TECHNOLOGY
INSIGHTS

DRAFT

HydroCatalysis Technical Assessment

Prepared for
PACIFICORP

Prepared by

TECHNOLOGY INSIGHTS
6540 Lusk Boulevard
Suite C-102
San Diego, CA 92121
619-455-9500

August 2, 1996

TECHNOLOGY INSIGHTS

Copy No. 1

R.L. Mills

Recipient

DRAFT

HydroCatalysis Technical Assessment

Prepared for
PACIFICORP

Prepared by

TECHNOLOGY INSIGHTS
6540 Lusk Boulevard
Suite C-102
San Diego, CA 92121
619-455-9500

August 2, 1996

DRAFT

TABLE OF CONTENTS

DRAFT

LIST OF FIGURES

LIST OF TABLES

1.0 Introduction

This report documents a technical assessment of a novel source of energy from hydrogen advanced by HydroCatalysis Power Corporation (HPC) (Ref. 1). It is an extension, drawing from HPC confidential data, of an earlier report based on publicly available information (Ref. 2). HPC represents that energy can be generated by a catalytic reaction allowing hydrogen atoms to achieve more stable states below the ground state established by generally accepted atomic theory, resulting in the release of energy and formation of a new form of low energy hydrogen, labeled hydrino (the term hydrino refers to both individual low energy hydrogen atoms and low energy hydrogen gas). The theory behind this concept, developed by Dr. Randell Mills of HPC in collaboration with Dr. John Farrell of Franklin and Marshall College (Ref. 3), remains controversial and has not received broad acceptance within the scientific community. Given the complexity, and the profound and comprehensive nature of Mills' theoretical work, immediate acceptance would not be expected even if the theory is absolutely correct.

The assessment was conducted by a literature search and review, site visits to HPC and collaborating organizations, and telephone interviews with others active in the general area. A description of the concept is provided in Section 3. Section 4 presents an assessment of the concept background, supporting theory, laboratory prototypes and projected initial products, economic and environmental aspects. Section 5 documents the results of telephone interviews and site visits. An overall summary and conclusions are presented in the following section.

2.0 Summary and Conclusions

It would be difficult to overstate the potential significance of either the theory or the practical applications arising from the theory advanced by HPC. If validated, the theory would represent one of the most fundamental advances in the history of science, revising models of matter and energy from the subatomic level to the history and structure of the universe. If reduced to practice as a new energy source as projected by HPC, the concept will have a profound effect on the world economic, political and social structure. It would seem unlikely that a discovery of such magnitude would arise from such obscure beginnings. However, the results of this assessment indicate that while it may be unlikely, it may also be true. The following observations are noted:

- The theoretical basis for the HPC concept was originally published in 1989, and has remained essentially constant in its fundamental elements since that time. It has languished in obscurity for the most part, with a few informed supporters substantially outnumbered by detractors. However, it appears to be gaining respect and attention of late fueled by an increasing number of validating observations at the atomic and astrophysical level. Some limitations and contradictions were noted by an informed supporter, and

significant revisions and extensions could be expected if the major elements become generally accepted and the subject of widespread research.

- HPC has used the theory to guide the development of energy cells based around the release of energy from hydrogen by a catalytic reaction which allows hydrogen to achieve energy levels below the observed "ground state". Experimental devices have evolved from a water based electrolytic cell operating at low temperatures and power densities to hydrogen gas cells operating at increasing temperatures and power densities. HPC's success in applying the theory for this purpose is a significant factor supporting its general validity.

- A majority view among technically qualified individuals that have worked with the electrolysis cells evolved by HPC is that some form of excess heat has been produced which is not explainable by conventional chemical processes. This view is not unanimous, and the degree of acceptance decreases with decreasing proximity to and understanding of the experiments. The conclusion of this assessment is that data from experiments on the electrolytic cells are sufficient to demonstrate the production of excess heat. However, consistent with the conclusion of HPC and others, electrolytic cell performance is not sufficient to support commercial applications for energy generation.

- HPC began working on hydrogen gas based cells about two years ago and has recently (beginning in January, 1996) developed a relatively simple vapor phase concept. Analysis of data obtained from HPC indicate power densities in the range of 1-4 Watts/cc, and possibly as high as 30 Watts/cc have been obtained. The progress achieved by HPC on the vapor phase concept over the past seven months has been impressive and provides a basis for optimism regarding the commercial potential of this concept.

- HPC has developed and refined procedures for identification of low energy hydrogen atoms, called hydrinos, and lower energy hydrogen molecules, called dihydrinos, produced during operation of their cells. Evidence supporting the existence of hydrinos and dihydrinos has been developed by HPC and by independent laboratories. Indications consistent with projected characteristics of hydrinos have been obtained from three independent procedures. Two additional tests which could provide definitive evidence of hydrinos have been identified and one or both may be conducted in the near future.

- Westinghouse has been following HPC's work for several years, conducting independent testing of electrolytic cells in 1993/94 through their Science and Technology Center (STC). They currently have an internally funded project to review the supporting information on the HPC concept and to support experiments at Penn State directed toward identification and characterization

of hydrino. STC has a commitment to reach a definitive conclusion and recommendation regarding the HPC concept by the end of 1996.

- The HPC theory and the projected characteristics of hydrino have been used to explain solar and deep space spectral observations in the soft X-ray and ultraviolet regions. HPC is working with the National Radio Astronomy Laboratory (NRAO) to conduct an experiment later this fall which could provide more conclusive results regarding the existence of hydrino, and in the process may contribute to a fundamental revision in the accepted model of the universe. However, discussions with a participant from the NRAO indicate that the experiment has not yet been approved, is challenging, and may not lead to conclusive results.

- Assuming the HPC concept is successful, the energy content of hydrogen is nominally estimated to be increased by at least a factor of 70 over hydrogen combustion. By another form of comparison, the resulting energy content of water would be at least 30 times that of gasoline.

- Assuming the process can be adapted to a gas turbine application, a net economic advantage of 1 to 2.5¢/kWh relative to a natural gas fired combined cycle gas turbine is projected. With a market share of 33% of current world electricity consumption, 2¢/kWh would translate to $66 Billion/year.

- The environmental releases associated with the HPC process would be far below fossil generation options that represent the majority of existing generating capacity and new capacity additions. In fact, oxygen release is likely to be considered a benefit, offsetting some of the reduced oxygen production arising from a reduction in tropical rain forests. A possible environmental concern could arise from the fact that water used to produce hydrino will be permanently lost from the planet. However, it was estimated to take 370,000 years to consume an inch of the ocean while supplying 33% of the current world electricity consumption.

On the whole, a significant and growing body of data supporting the validity of the HPC theory and hydrogen energy concept was identified. Some uncertainty remains regarding the identification and characterization of hydrino. A greater level of uncertainty is associated with the reduction of the energy concept to practice in the projected applications, but recent progress provides a strong basis for optimism regarding ultimate success. Key issues to be addressed in conjunction with developing the concept into a commercial product are increasing the reaction power density and establishing an energy cell and supporting auxiliaries design that provides the necessary degree of controllability for integration with a power conversion system. Telephone interviews and site visits to HPC and collaborating organizations covered the full range of functions from validating research through concept optimization and energy cell engineering. In all cases, the individuals involved were found to be

exceptionally capable and professionally qualified to address the challenging tasks that remain to bring the concept to the point of integration with commercial power conversion or heat utilization systems.

3.0 Concept Description

The HPC concept is based on modifications to existing theory which, if proven correct, would represent a major advance in the understanding of matter and energy. The theory was developed by Dr. Randell Mills, the founder of HPC, in collaboration with Dr. John Farrell of Franklin and Marshall College. One of the predictions of the theory is the existence of nonradiative states of the hydrogen atom below the "ground state" defined by existing theory. Dr. Mills believes he has developed a means of achieving these lower level energy states, liberating energy in much larger amounts than are obtained from the combustion of hydrogen. The theory behind the concept, existing laboratory prototypes, and projected initial products are summarized in the following subsections.

3.1 Background/Theory

The HPC concept originated in the same time frame as the "cold fusion" concepts, which came to public and general scientific attention in 1989 (Ref. 4, 5, 6). As attempts to explain the excess heat apparent in the experiments proliferated, possible phenomena beyond fusion have been introduced. Because of its widespread use in earlier years, the term "cold fusion" has evolved to encompass broader theories and processes for excess energy generation. While the Mills theory does not involve nuclear fusion, the theoretical basis for the HPC concept originated in parallel with the "cold fusion" experiments, and the initial HPC experimental procedure was similar to those used in the early "cold fusion" experiments, thus the concept has often been viewed within the general framework of "cold fusion". Since the HPC concept does not involve fusion, and given the negative perceptions and controversy associated with cold fusion, HPC has attempted to distance itself from the cold fusion community.

The energy released in the HPC process is postulated to be released by a catalytic reaction which allows hydrogen atoms to achieve a lower energy than their naturally occurring "ground state". Because of its simplicity relative to other elements, hydrogen was the subject of a great deal of scientific attention in the late nineteenth and early twentieth centuries. Experimental observations of hydrogen behavior were used to gain a more detailed understanding of the nature of matter at the submicroscopic level. A primary piece of evidence was the discrete bands of light emitted by hydrogen gas during combustion and other forms of excitation. These data were used to construct a model of the atom consisting of discrete energy levels associated with allowed orbits of the electron about the nucleus, with the observed radiation emissions associated with changes in energy levels arising from transitions among these orbits. Quantum numbers were assigned to the orbits beginning with the

lowest observed energy state, which was assigned the quantum number n=1. Additional theoretical refinements resulted in the development of models treating matter as having both particle and wave properties. The evolving understanding was given mathematical formalism through the Schrödinger equation, which was used with various assumptions and boundary conditions to make further explanations of experimental observations.

Dr. Randell Mills, the founder of HPC, in collaboration with Professor John Farrell of Franklin and Marshall College, developed the theory on which the HPC concept is based, and initially published their results and conclusions in 1989 (Ref. 3). The Mills theory represents a modification and extension of the fundamental representation of matter and energy developed primarily in the early twentieth century. One result of the theory is a prediction that additional lower energy states are possible for the hydrogen atom, but are not normally achieved because transition to these states is not directly associated with the emission of radiation, thus the hydrogen atom as well as lower energy hydrogen atoms (hydrinos) are stable in isolation. It is postulated that hydrogen atoms (and other single electron atoms, e.g., He ion) can achieve these states by a "resonant collision" with a nearby atom or combination of atoms having the capability to absorb the energy required to effect the transition. The following summary of the process is taken from Ref. 7:

> "The quantum number $n=1$ is routinely used to describe the "ground" electronic state of the hydrogen atom. Dr. Mills shows that the $n=1$ state is the "ground" state for "pure" photon transitions (the $n=1$ state can absorb a photon and go to an excited electronic state, but it cannot release a photon and go to a lower-energy electronic state). However, an electron transition from the ground state to a lower-energy state is possible by a "resonant collision" mechanism. These lower-energy states have fractional quantum numbers, $n=1/integer$. Processes that occur without photons and that require collisions are common. For example, the exothermic chemical reaction of $H + H$ to form H_2 does not occur with the emission of a photon (Ref. 8). Rather, the reaction requires a collision with a third body, M, to remove the bond energy - $H + H + M \rightarrow H_2 + M$. The third body distributes the energy from the exothermic reaction, and the end result is the H_2 molecule and an increase in the temperature of the system. Similarly, the $n=1$ state of hydrogen and the $n=1/integer$ states of hydrogen are nonradiative, but a transition between two nonradiative states is possible via a resonant collision, say $n=1$ to $n=½$. In these cases, during the collision the electron couples to another electron transition or electron transfer reaction which can absorb the exact amount of energy that must be removed from the hydrogen atom, a resonant energy sink. The end result is a lower-energy state for the hydrogen and an increase in the temperature of the system. The reaction of hydrogen to lower-energy states is referred to as a transition reaction. Certain inorganic ions which are proprietary to the Company serve as transition catalysts which resonantly accept energy from hydrogen atoms and release the energy to the surroundings. The transition catalyst should not be consumed in the reaction. It accepts energy from hydrogen and releases the energy to the surroundings.

Thus the transition catalyst returns to the original state. And, the energy released from hydrogen atoms is very large compared to conventional chemical reactions including the combustion of hydrogen. Multiple cycles of catalysis are possible with increasing amounts of energy with successive cycles of transitions."

Potassium (K^+) is identified as having a transition energy level that matches with the calculated hydrogen atom energy exchange (27.2 ev) needed to effect a transition from the generally accepted "ground state" associated with quantum number n=1 to a lower energy state associated with $n=½$, and to other lower level fractional states. Thus potassium is considered a potential catalyst for releasing the hydrogen energy. The $n=1 \rightarrow n=½$ reaction involves a hydrogen atom and two potassium atoms which undergo changes in ionization state, resulting in a net release of energy (40.8 ev) and a shrunken hydrogen atom, identified by Mills as a "hydrino". Subsequent additional lower level transitions are predicted to occur, increasing the energy release per atom by the process. These postulated reactions form the basis for the HPC concept, which for the purposes of this assessment is assumed to result in an average energy release of 100 ev/atom. In comparison, the combustion of hydrogen in a conventional chemical reaction releases about 1.5 ev/atom.

3.2 Evolution of Laboratory Prototypes

Dr. Mills has been developing reaction cells to test the theory and demonstrate the release of energy and formation of hydrinos since 1989. The initial cells used water based electrolyte, and several variants have been described in the open literature. More recently, higher temperature cells have been developed using hydrogen gas.

3.2.1 Water Based Electrolyte Cell (Low Temperature)

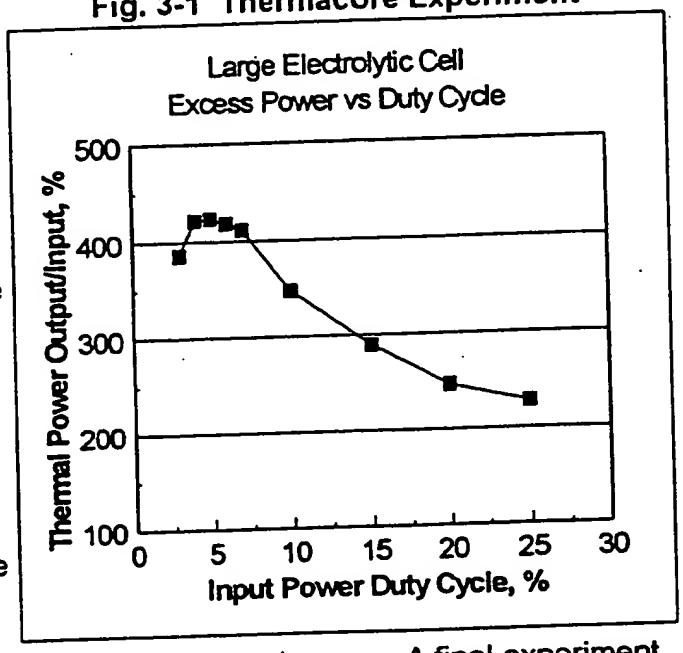
Construction and operation of an early (1990) version of a water based electrolyte cell was described in Ref. 9. The cells used were relatively small, containing 100 ml of electrolyte. The base case cell was constructed using a nickel foil cathode and a platinum wire anode, with a potassium carbonate (K_2CO_3) electrolyte for most of the runs performed. Electrolysis of the electrolyte by passing a current through the electrodes was postulated to allow hydrogen and potassium atoms at the surface of the cathode to interact, resulting in the release of energy. Control cases used a sodium carbonate (Na_2CO_3) electrolyte, which was not expected to produce excess heat according to Mills' theory. Variables studied included electrode and vessel configurations, cell stirring and power application (square wave vs. dc). Power generation in the cell was calculated from cell temperature, based on a calibrated conductive heat loss path to ambient. A total of 29 cases using K_2CO_3 electrolyte with voltage applied to the electrodes were reported. Excess power represented to be coming from the hydrogen reaction was reported in all cases, ranging from 1.5 to 40 times the net input power (total power to the electrodes minus the water electrolysis power).

Additional electrolytic cell results were reported by HPC and Thermacore in Ref. 10, as summarized below.

- HPC reported results from three experiments in a cell somewhat larger (350 ml) than the earlier cell noted above. Excess power was reported in the experiments conducted using a potassium carbonate electrolyte (output/input of 200% for continuous, 1600% for pulsed input). No excess power was reported for the control experiment using sodium carbonate, consistent with the Mills theory.

- Thermacore reported results from 11 experiments conducted in a much larger (10 gallon) cell. It had been observed that higher excess power was obtained in a pulsed input power mode, using a low frequency (1-2 Hz) square wave. Nine of the Thermacore experiments consisted of varying the duty cycle (percent of time the voltage was applied) of the input square wave while holding other variables constant, with results shown in Fig. 1. The results indicate a well behaved process producing excess power beyond what could be explained by measurement errors. A final experiment conducted at a lower input power with a duty cycle of 20% was operated for 240 days with an output/net input power ratio in excess of 2000%.

Fig. 3-1 Thermacore Experiment



A later, more advanced cell was operated in 1994, as described in Ref. 11. This cell was much larger than the earlier HPC cells, containing 11 liters of electrolyte. The cathode was constructed of nickel wire cloth and the anode of a nickel fiber mat, providing a large reaction surface area for each. The cell was placed in a dewar to minimize uncontrolled heat loss, and heat removal was through a controlled and instrumented condenser. Cases were run using K_2CO_3 electrolyte, expected to produce excess power via catalysis of the hydrogen energy release by the potassium in accordance with Mills' theory, and Na_2CO_3, which was not expected to produce excess power. A calibration run (no voltage applied to the electrodes, while an internal resistance heater was operated) was performed for each electrolyte. Both Na_2CO_3 cases and the K_2CO_3 calibration run were operated for 7 days, while the K_2CO_3 electrolysis run was operated for 14 days. Excess power in the K_2CO_3 electrolysis run was measured at 17.6 times the net input power.

DRAFT

3.2.2 Gas Cell

A new approach using hydrogen gas in a reaction cell was begun in 1993 and has advanced considerably over the past year. Recognizing the limitations in temperature and power density capabilities of the electrolytic cells that had served to provide evidence of the production of excess heat and the existence of hydrino, HPC proceeded to develop new concepts based on using hydrogen gas as an input to the cell rather than producing it in the cell through electrolysis. This concept provides the potential for achieving much higher temperatures and power densities than have been achieved in the electrolytic cells discussed above. The evolution of the gas cell concept is summarized below, followed by additional discussion of the most recent and most promising concept, the vapor phase cell in the following section.

The gas cell concepts introduce hydrogen into the cell in gaseous form rather than generating hydrogen by electrolysis of an aqueous solution in the cell, as is done in the electrolytic cells. Guided by Mills' theory, the objective of all of the concepts is to produce a local mixture of hydrogen atoms and catalyst ions, thus allowing the catalytic reaction to produce low energy hydrogen. An initial concept added hydrogen to a potassium carbonate solution via a coil of nickel tubing. Subsequent concepts moved toward introducing hydrogen gas directly in the cell, using initially a sintered catalyst, then a spillover catalyst, and most recently a vapor phase cell. The characteristics of these concepts are summarized below.

- **Hydrogen Diffusion/Aqueous Solution** - This concept was developed by Thermacore, working in collaboration with HPC. Hydrogen was introduced into the cell through a coil of thin-walled nickel tubing placed inside a pressurized vessel containing a solution of K_2CO_3. Hydrogen atoms could then diffuse through the nickel and react with the potassium on the outer surface of the tubing. By using a pressurized vessel, higher temperatures and pressures (relative to atmospheric pressure aqueous solution electrolytic cells) were achieved. Excess power was observed in these cells as reported in Ref. 12, proving that excess power could be produced without electrolysis. However, Thermacore was unable to achieve sufficient power densities to support commercial applications.

- **Solid State Catalyst** - Seeking to develop a concept with more economic potential, HPC began to investigate cells which would involve the direct interaction of hydrogen gas and a solid state catalyst. Initial concepts were based on a sintered metal oxide compound mixed with a catalyst material to induce the low energy hydrogen reaction. Tests at Penn State showed indications of excess power (Ref. 13) interpreted by HPC to be produced by transition of hydrogen to lower levels (hydrino). The solid state catalyst approach was further evolved through the development of hydrogen spillover catalysts consisting of mixtures of hydrogen dissociation materials and catalytic materials on graphitic carbon powder. Tests at Penn State also

demonstrated the production of excess power from spillover catalyst cells (Ref. 14, 15). In evaluating the results of the testing on the spillover catalyst cells, HPC concluded that excess power was being produced, but recognized that the catalyst was being neutralized after a period of time, eventually terminating the reaction, thus this concept would require catalyst replenishment for sustained operation.

- **Vapor Phase Cell** - In reviewing the results of the spillover catalyst cell testing, HPC concluded that the reaction may have been taking place in the vapor phase, leading to the development of a vapor phase cell as the current leading concept for energy production. The vapor phase cell consists of a means for establishing catalyst atoms in a gaseous state along with hydrogen atoms, thus supporting a catalytic reaction in the vapor phase. This evolution reduces the device to the basic elements predicted by the theory to produce low energy hydrogen: atomic hydrogen and catalyst ions to provide the required energy hole. The theory also predicts that optimum performance will be obtained at a low pressure (less than 1/1000th of an atmosphere. The prediction of optimum pressure is based on the development of the disproportionation reaction concept based on observation of solar reactions. With disproportionation, a hydrino atom can catalyze further collapse of another hydrino atom. At lower pressures recombination of hydrogen and hydrino atoms into molecules via collision with other atoms is less likely, thus the reaction can be more effectively sustained. The concept is discussed in more detail in the following section.

3.3 Basic Features and Performance of Vapor Phase Cells

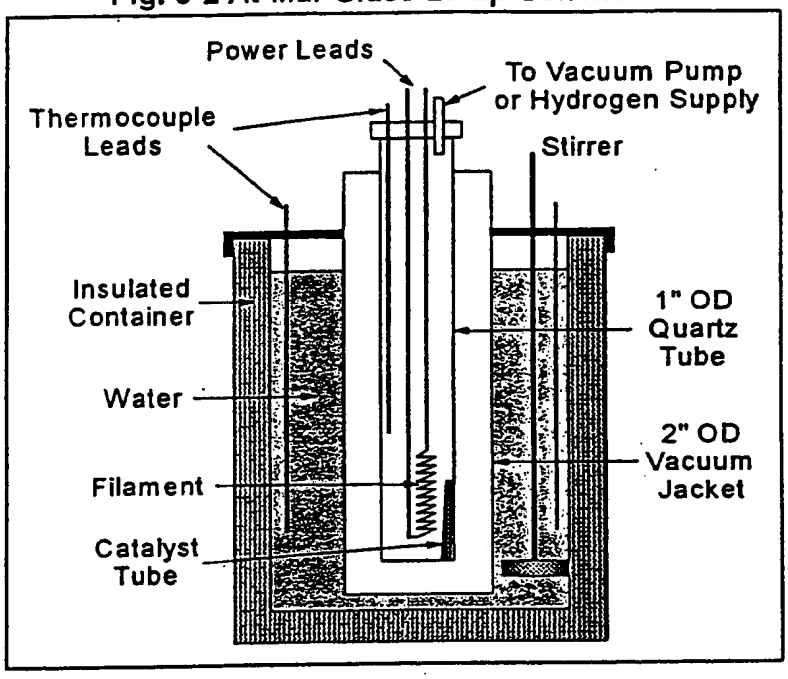
HPC began work on their first vapor phase cell concepts in January, 1996, constructing small tabletop systems with one running at a time. Based on early successes, a priority effort was begun in the spring of 1996. As of July, 1996, several variants of vapor phase cells have been constructed and operated at HPC and most recently at Pennsylvania State University. In most cases, they have consisted of a vessel containing a powered metal filament to dissociate hydrogen molecules, a compound to produce catalyst atoms at the desired vapor pressure and operating temperature, an attached vacuum pump to provide for initial purging of contaminants and to achieve and maintain the desired operating pressure, and a source of hydrogen gas. For control experiments, provisions may also be included for a non-dissociating heat source (e.g., cartridge heater) in addition to a metal filament, and provision for introducing neutral gas (e.g., helium) and non-catalytic compounds (e.g., sodium compounds). A recent variant utilizes a metal powder for dissociation of hydrogen molecules in conjunction with an external heater to achieve desired operating conditions. HPC reports that excess power is being observed in all of the vapor phase variants. A brief description of the devices and a summary of recent results is provided in the following subsections.

DRAFT

3.3.1 At-Mar Glass Lamp

A small gas vapor cell referred to by HPC as an "At-Mar Glass Lamp" is shown in Fig. 3-2. In this device, a vacuum pump is used to evacuate the cell and bake out impurities, then the cell is filled with hydrogen at a low pressure (~1 torr). Hydrogen atoms are produced by dissociation of hydrogen molecules by the high temperature filament (typically tungsten). A small tube of a catalyst compound (e.g., KNO_3) is placed alongside the filament to serve as a source of catalyst atoms. The device is placed in an insulated container partially filled with water kept at a uniform temperature by a stirring device and brought to an initial equilibrium temperature.

Fig. 3-2 At-Mar Glass Lamp Schematic

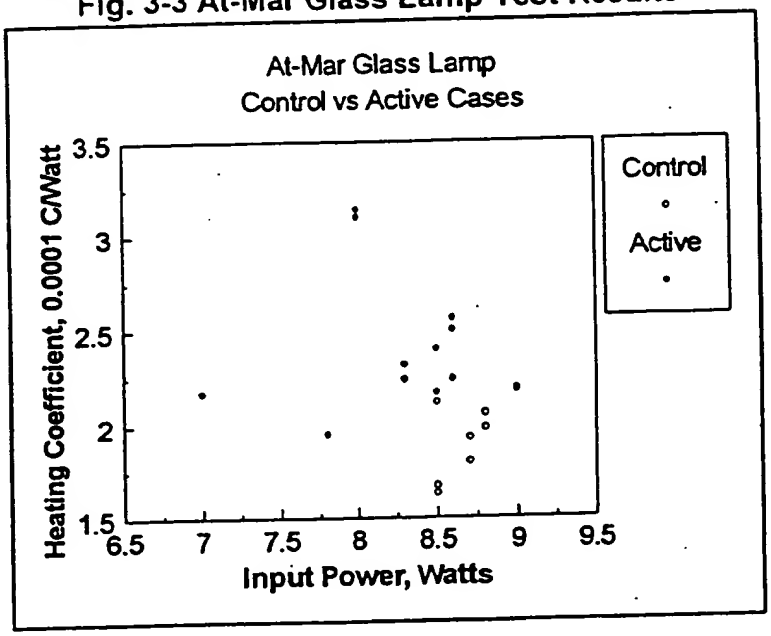


Power is applied to the filament and the temperature of the water is monitored by two thermocouples to determine the rate of increase of water temperature at a constant, measured level of input power. The cell heating coefficient ($\Delta T/\Delta t$/Power, °C/Watt-second) is determined for a set of control cases for comparison with cases where conditions supporting low energy hydrogen production are present. For some of the runs, the internal surface of the quartz tube was plated with silver to reduce radiant heat loss and thus increase the operating temperature of the cell.

HPC has conducted a series of experiments using the At-Mar Glass Lamp device to investigate the production of excess energy. A set of control cases were

operated with hydrogen and power to the filament, and compared with a set of active cases in which a potassium catalyst compound was added. The results are shown in Fig. 3-3. A considerable scatter in the results is present, with average values for the Heating Coefficient (10^{-4} °C/Watt-second) of 1.91± 0.19 for the control cases and 2.37 ± 0.35 for the active cases. Calculating the excess power ratio as the ratio of the heating coefficient for the active cases over the control cases, excess power would be about 20% of input, or about 2 watts on average.

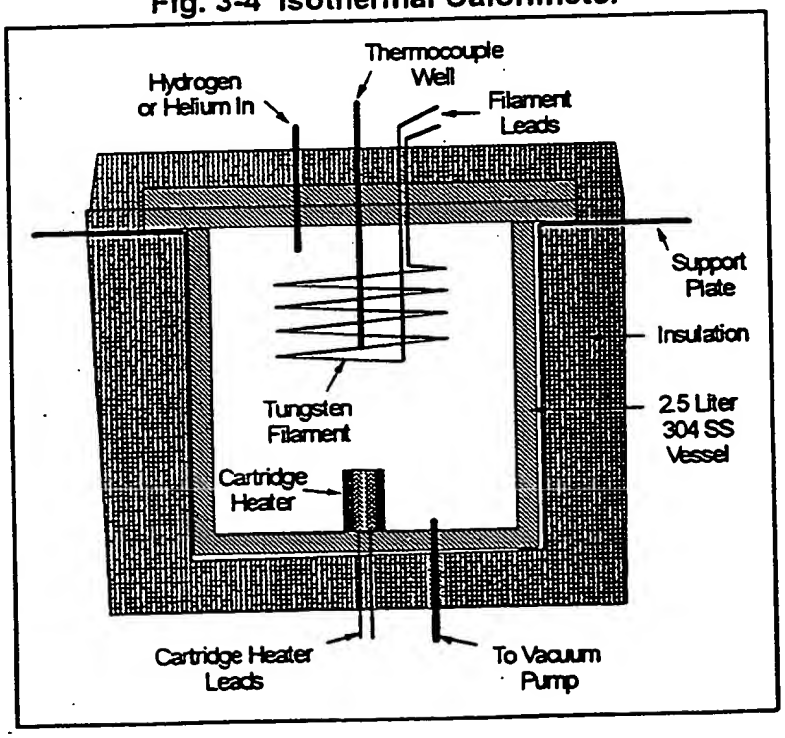
Fig. 3-3 At-Mar Glass Lamp Test Results



3.3.2 Isothermal Calorimeter

A schematic diagram for a larger (2.5 liter volume) HPC vapor phase cell operating on the same principle as the At-Mar Glass lamp, and designated the Isothermal Calorimeter is shown in Figure 3-4. The Isothermal Calorimeter Cell has been operated in a combination of control and active experiments to study the effect of key parameters (i.e., presence of catalyst and hydrogen gas, means for dissociation of hydrogen molecules). In a typical experiment, the vessel is pumped down and baked out to remove contaminants, then the desired conditions are established and the temperature is monitored until equilibrium is reached. For example, a control experiment

Fig. 3-4 Isothermal Calorimeter



DRAFT

might use the cartridge heater instead of the filament to heat the vessel without dissociation of hydrogen gas. A series of experiments reaching equilibrium at about the same temperature was conducted with various combinations of the key parameters, while noting the input power required to achieve the target temperature. Assuming the heat loss from the cell is the same in all cases, the excess power generated in the cell would be the difference between the input power in the control cases and the input power in an active case. Data from a series of runs performed at HPC during June, 1996 at 260 to 290°C were analyzed assuming vessel heat loss is linearly proportional to indicated temperature, with results as shown in Figures 3-5a and 3-5b. The results in Figure 3-5a show excess power as a function of input power for a series of cases grouped based on (1) no potassium present, (2) potassium but no hydrogen, (3) potassium and hydrogen but no power to the filament, and (4) potassium, hydrogen and power to the filament. Figure 3-5b shows the same excess power results plotted as a function of the number of key conditions present during the test. The data indicate a large amount of excess power for the cases where all of the conditions for the HydroCatalysis reaction are present.

Fig. 3-5a Isothermal Calorimeter Test Results

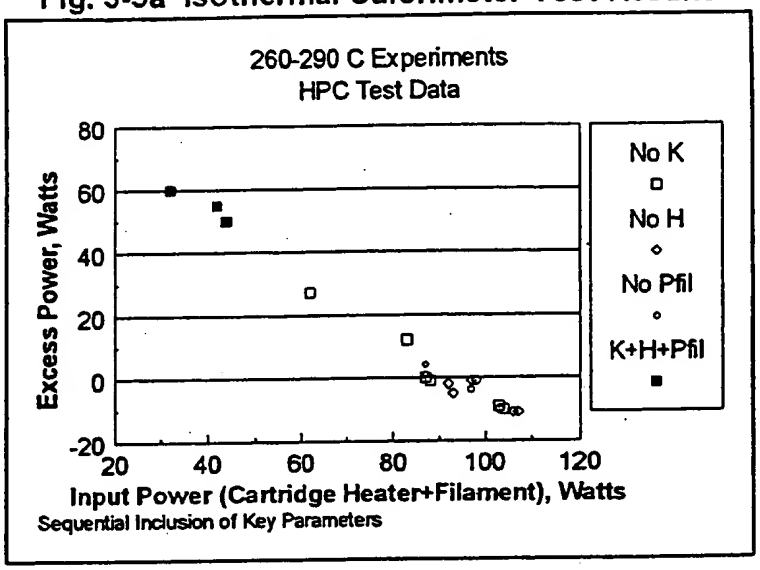
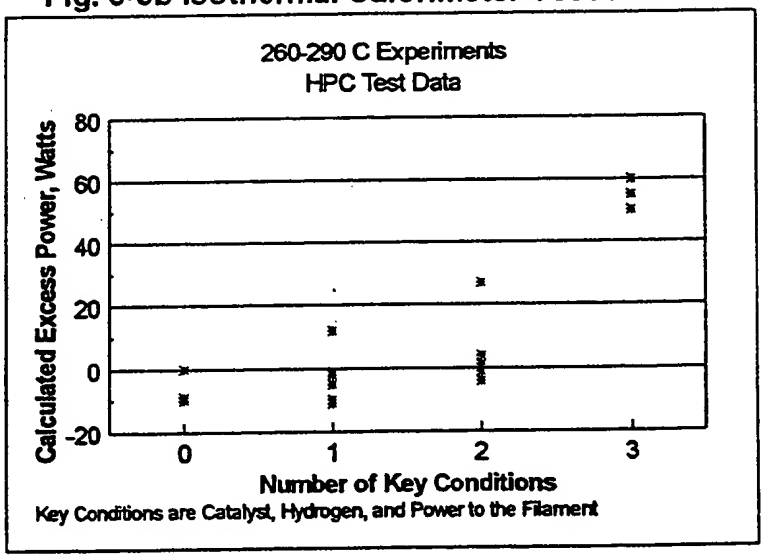


Fig. 3-5b Isothermal Calorimeter Test Results



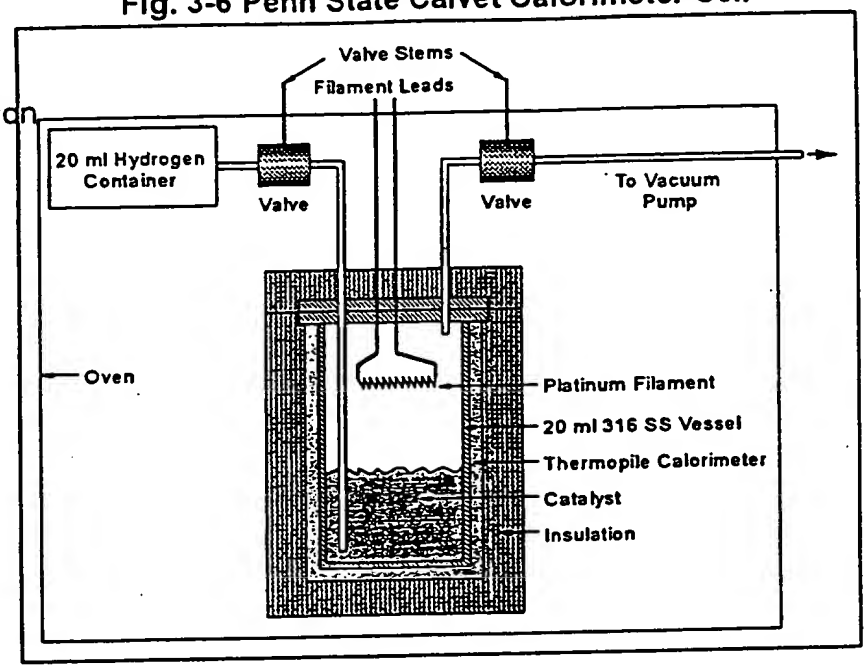
3.3.3 Calvet Calorimeter Cell

Another cell variant based on the same principle as the At-Mar Glass lamp is a small metal vessel cell operated within an oven to establish a well controlled operating temperature. These cells have been operated in multiples with simultaneous operation

DRAFT

of control and active cells to investigate excess power generation, and in combination with a precision thermopile based calorimeter, called a Calvet Calorimeter. Independent testing of a Calvet Calorimeter Cell began at Penn State in mid-July, as noted in the summary of a visit to Penn State provided in Section 5.2.3. A schematic of the device constructed at Penn State, which is similar to corresponding cells operated at HPC, is shown in Figure 3-6. As discussed in Section 5.2.3, the cell was operated at near atmospheric pressure at an input power of 5 Watts, with preliminary analysis indicating the production of excess power in the range of 0.01 to 0.05 Watts over several days for a total energy corresponding to about 20 times the amount which would result from combustion of all of the hydrogen present in the cell and hydrogen reservoir. HPC reported excess power of 0.3 to 0.7 watts for a similar cell operating at a hydrogen pressure of about 200 millitorr and an input power of about 4 Watts.

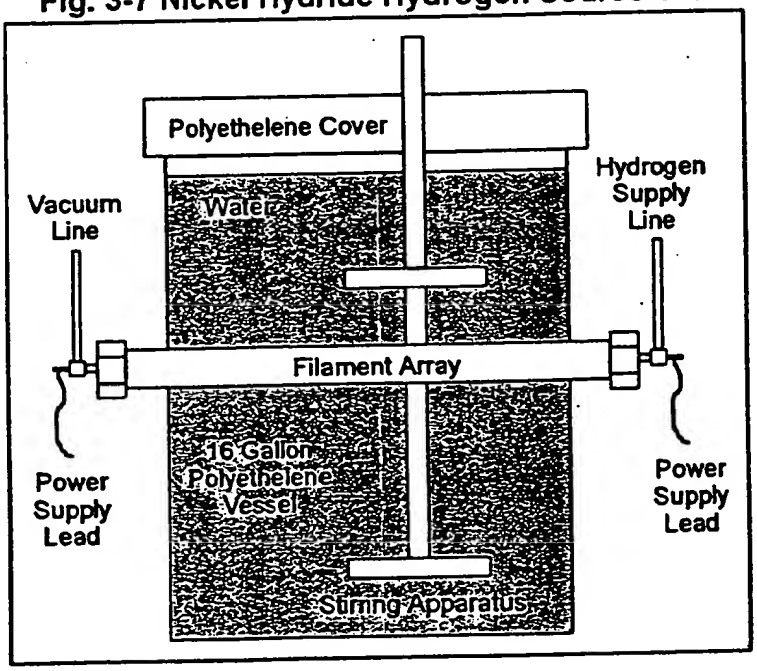
Fig. 3-6 Penn State Calvet Calorimeter Cell



3.3.4 Metal Hydride Hydrogen Source Cell

Another concept pursued by HPC involves the use of hydrided metal as a hydrogen source (Figure 3-7). In these devices, nickel wire which had been used as a cathode in an electrolytic cell is used as a filament in a gas cell. The nickel wire is wrapped around a quartz tube or mandrel, electrical leads are attached, and the assembly is placed inside a larger quartz

Fig. 3-7 Nickel Hydride Hydrogen Source Cell



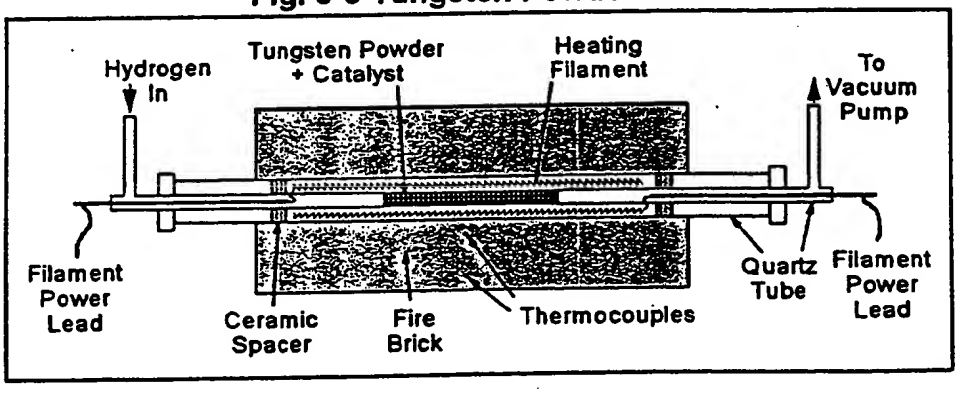
tube. The larger tube is epoxied into a large water container, the ends are sealed, the larger tube is evacuated, and power is applied to the filament. As the filament temperature increases, hydrogen stored in the nickel during earlier electrolytic cell operation is released along with potassium which had plated out on the surface. The released potassium serves as the catalyst in some experiments, while others include additional catalyst compound which is vaporized as the cell reaches operating temperature. The water in the container is stirred as power is applied to the cell, and energy input to the water (output power from the cell) is determined from the rate of temperature rise. Additional control experiments have been conducted to improve the accuracy of the determination of cell output power.

HPC reported that early tests which relied on potassium plated out on the nickel wire as the source of catalyst atoms were erratic in their performance, and it was concluded that a separate source of catalyst should be added to the cell. Thus a quartz capillary containing a catalyst compound was placed inside the inner quartz tube for subsequent tests. Testing of the nickel hydride gas cell concept was conducted by varying input power over a range of approximately 400 to 800 watts. For these runs measured excess power ranged from 40 to 120 watts (6 to 17% of input power). A test in late July was reported to have produced approximately 250 watts of excess power with an input power of 170 watts. HPC believes the increased power may be a result of a disproportionation reaction supported by hydrino atoms released from the nickel wire. HPC also believes their earlier gas cells were limited by the hydrogen atom densities in the cells, and have evolved their devices to provide adequate hydrogen atom density. They feel that current results are being limited by catalyst atom density, and are directing device design and operation to address this limit.

3.3.5 Tungsten Powder Cell

Another gas cell concept being pursued by HPC is the use of tungsten powder rather than a tungsten filament for hydrogen dissociation. In this concept, as depicted in schematic form in Fig. 3-8, the reaction chamber is a quartz tube containing tungsten powder and a catalyst compound. The tube is surrounded by a heating filament to achieve the required temperatures to dissociate hydrogen on the tungsten. Results from a series of tests initiated in July are reported to indicate about 10 watts excess power. This concept is in the early stage of

Fig. 3-8 Tungsten Powder Cell



development, and can be expected to undergo significant refinement as a result of initial testing.

3.4 Applications and Projected Products

HPC has begun to explore concepts for application of the technology for electricity generation. These concepts, currently in a very early stage of development, are based on using the heat energy developed by the hydrogen transition reaction in conjunction with conventional power conversion equipment. Applications envisioned include:

- 10 kW units for heat and electricity in residential applications
- Industrial cogeneration and distributed generation applications in the 100 kW to multi-megawatt range
- Large central station applications, including units for retrofitting fossil boilers and repowering nuclear plants

The initial products are at a very early conceptual stage, with no evidence of detailed conceptual design development and review. The thinking to date has been based on using the gas reactor in a heat exchanger configuration to generate steam or integrated into a gas turbine. Other applications are envisioned including motive power for automobiles, trucks, etc.

4.0 Concept Assessment

This section discusses the results of the concept assessment. Subsections 4.1 and 4.2 address the validity of the theory and the experimental basis for the generation of excess heat from the HPC process. Subsections 4.3 and 4.4 address potential initial products and their projected economic and environmental characteristics, assuming the HPC process is proven and commercially viable.

4.1 Theory

The generally accepted theory of the hydrogen atom and the broader quantum mechanics models upon which it is based are supported by a long standing body of analytical models and empirical observations. The mathematics and empirical data involved are of sufficient complexity and magnitude to support years of study and controversy before acceptance of major new developments or changes in accepted interpretations. The Mills theory proposes changes in interpretation of quantum mechanical phenomena relative to the hydrogen atom and other physical phenomena on a scale not seen since early in this century. Thus it is not surprising that the theory

is controversial and not readily accepted by the scientific community. However, it appears that a small but expanding number of scientists are beginning to take the Mills theory seriously.

The Mills theory has been documented in a series of publications, beginning with Ref. 3, with the most recent revision provided in Ref. 16. A review of one of the publications, Ref. 17, was documented by Dr. Reinhart Engelmann of the Oregon Graduate Institute of Science & Technology, Ref. 18. In summary, Dr. Engelmann stated "I am confident that the soundness of your basic, though unusual, approach to quantum theory, combined with convincing experimental results, should eventually convince a broader scientific community". As evidence is accumulating in support of the existence of hydrino, it appears that this broader acceptance is beginning to happen.

Given the time and resource limitations of this assessment, it was not considered productive to attempt an in-depth review of the theory. However, discussions with Dr. Stewart Kurtz (Section 5.1) of Penn State indicate that the theory has received considerable review by reputable physicists over the past several years, resulting in extensions of the phenomena addressed by Mills, but no fundamental flaws in the theory have been identified. Dr. Reinhard Engelmann of the Oregon Graduate Institute of Science & Technology has also spent considerable effort reviewing the theory and its mathematical derivation (interview summary, Section 5.1). Dr. Engelmann indicated a strong belief in the general validity and importance of Mills' theory, but expressed concern regarding some inconsistencies in the theoretical framework which he was unable to resolve. He feels that what is needed is for others to become interested and begin working on the mathematical development of the theory, and believes that the best way to make that happen is to advance an energy generation device and expand the empirical evidence supporting the theory. Consistent with this view, attention was focused on the case for the existence of the postulated results - the hydrino - and the degree of confidence in the observation of excess energy in the cell experiments conducted by HPC and others. The cell experiments are addressed in Section 4.2, and the case for the existence of hydrino is addressed below.

4.1.1 Hydrino - Laboratory Observations

If the theory is valid, hydrino could be expected to be found as a residual product from the operation of the HPC cells, but hydrino would not be easily detected because of its predicted high degree of stability, making it relatively inert, and its expected tendency to diffuse readily. Two methods for detecting hydrino as a byproduct of the reactions in the cells have been presented in the open literature, and a third has been recently advanced by HPC as summarized below:

X-ray Photoelectron Spectroscopy (XPS) - XPS was used to search for evidence of the presence of hydrinos on the surface of the cathode material from

electrolytic cells. The XPS procedure utilizes an X-ray photon source to ionize atoms and measure the kinetic energy of the emitted electron. The binding energy of the emitted electrons can be determined from their kinetic energy and the known photon energy. The procedure results in a spectrum of binding energy peaks for materials present in the specimen. The binding energy for a n=½ hydrino would be 54.4 ev according to Mills' model. XPS data were developed for HPC specimens by the Zettlemoyer Center for Surface Studies, Lehigh University, with independent confirming data produced by the Idaho National Engineering Laboratory and Charles Evans & Associates. Ref. 11 reported XPS data for the following specimens:

- Nickel foil from a cathode which had been operated with K_2CO_3 electrolyte (no calorimetry)
- Nickel wire from a cathode which had been operated with K_2CO_3 electrolyte in a cell measured to be producing excess heat
- Nickel wire from a cathode which had been operated with Na_2CO_3 electrolyte
- Precursor nickel electrode material (pure, heated, and oxidized specimens)

A broad peak was observed in the vicinity of the predicted 54.4 ev binding energy of the hydrino for the first two cases and not for the remaining samples. Other nearby peaks were identified as being associated with nickel and known impurities in the samples. Mills & Good concluded that the observed broad peak was produced by hydrinos present on the samples which had been operated as cathodes in cells with K_2CO_3 electrolyte. The data presented in Ref. 11 are generally supportive of this conclusion, but are not totally convincing, in that apparently significant variations in the average energy of the observed peak are not explained in the paper. In subsequent discussions, Mills stated that the broadening of the peak is caused by Compton scattering, and that some drift in the measured energy levels can be expected for XPS measurements.

Recent unpublished XPS data associated with identification of hydrino were made available by HPC during the course of this assessment (Ref. 19, 20). Additional XPS testing has been conducted at Lehigh University on glassy carbon electrode materials taken from an electrolytic cell. The use of carbon electrodes eliminates the large peaks associated with nickel which were present with the nickel electrodes and thus reduces the potential for secondary peaks in the energy regions where hydrino would be expected. HPC has identified features in these data which they associate with the presence of n=$^1/_2$, $^1/_3$, and $^1/_4$ hydrinos. However, as noted in Section 5.2.4, Dr. Miller of Lehigh, who performed the XPS work, does not feel the data developed to date provides conclusive evidence of hydrino. Miller is concerned about the very small X-ray cross-section of hydrogen (0.0002 relative to a carbon baseline) and of hydrino by extension, implying a requirement for a very high density of hydrino on the specimen surface to generate a signal. In addition there is the possibility of a second order potassium peak associated with lower energy potassium peaks

which are present in the data. Miller believes that definitive results could be obtained by a gas phase experiment where the only material present is the gas from an HPC cell. He estimates that such an experiment would take between three and six months and cost between $100,000 and $200,000.

Mass Spectroscopy - Mills projects that if hydrinos are present on the cathode metal surface, they would bind together to form "dihydrinos", the equivalent of hydrogen molecules. These dihydrinos would be expected to be present in the electrolysis gases along with molecular hydrogen and oxygen. Mass spectroscopy was performed on electrolysis gas samples from K_2CO_3 and Na_2CO_3 cells along with control hydrogen samples by Schrader Analytical and Consulting Laboratories. An additional gas sample from a K_2CO_3 cell was ignited with the objective of increasing the dihydrino fraction through combustion of much of the hydrogen and oxygen, thus increasing the hydrino fraction (termed postcombustion gases). The following tests and observations were reported:

- It was postulated that the dihydrinos would have considerably higher ionization energy than molecular hydrogen. Ionization potential was varied to identify thresholds for ionization of the molecules present, resulting in identification of a species with an ionization potential of 63 ev in the gases from the K_2CO_3 cell, well above the hydrogen molecule ionization potential of 15.46 ev. This species was not present in the gases from the Na_2CO_3 cell or the control samples.
- It was also postulated that while the mass/charge ratio for dihydrinos and hydrogen molecules would be indistinguishible, there would be a detectable difference in the magnetic moments of the two molecular ions. A double peak in the high resolution magnetic sector mass spectra at m/e=2 was observed for postcombustion gases at an ionization potential of 70 ev. The feature was not present for the gases at 25 ev or for a control hydrogen gas sample at 25 or 70 ev.

It was concluded that both observations are supportive of the presence of a species with the expected characteristics of dihydrino molecules in the gases from the K_2CO_3 cell.

Additional mass spectroscopy data have been developed by HPC utilizing off-gas from a vapor cell utilizing a Calvet calorimeter and gas collected from an electrolysis cell as discussed in Ref. 19 and summarized below.

- Gases were collected from a small (20 ml) gas vapor cell connected to a Calvet calorimeter for on-line detection of excess power production and passed through a mass spectrometer. Cell operating conditions were adjusted to obtain production of excess power in one case (as verified by the calorimeter) and to preclude production of excess power in a control case. The ionization potential of the mass spectrometer was varied back and forth

from 30 to 70 ev as the cell was operating. For the control case, the mass spectrometer was adjusted so that the signal remained relatively constant for the mass=2 species during the change in ionization potential. With the same mass spectrometer settings for the excess energy case, a large increase in signal was observed as a result of the change of ionization potential.

- Gases were collected from an evacuated hollow nickel cathode of an aqueous potassium carbonate electrolytic cell and an aqueous sodium carbonate electrolytic cell (control case). Each cathode was sealed at one end and was on-line to a mass spectrometer at the other end, allowing some of the gas produced during electrolysis to diffuse through the wall of the nickel tubing and flow to the mass spectrometer. The ionization potential of the mass spectrometer was varied between 30 and 70 ev and the response for mass=2 species was observed. Data from the control case (sodium carbonate electrolyte) indicated an approximately constant signal during the change in ionization potential (average ratio for 70 ev signal vs 30 ev signal = 0.9). Data from the potassium carbonate electrolyte case showed a significant increase in the signal in all cases (average ratio = 4.1).

Gas Chromatography - Gas chromatography was used to search for evidence of dihydrinos due to differences in magnetic energies relative to hydrogen molecules. As stated by HPC (Ref. 19): "Lower-energy hydrogen has an internuclear distance which is fractional compared with that of normal hydrogen. Thus, nuclear hyperfine structure interactions are greater. Also orbital magnetic hyhyperfine interactions are possible for lower-energy hydrogen. The ortho and para forms of molecular hydrogen can readily be separated by chromatography at low temperatures. Thus, we explored the possibility of using gas chromatography at cryogenic temperatures to discriminate hydrogen molecules from dihydrinos on the basis of the difference between magnetic energies of the two species."

Gas chromatography was performed on two sources: (1) A control sample of hydrogen gas produced by reacting NaOH with aluminum chips, and (2) a sample expected to contain lower energy hydrogen molecules (dihydrinos). The second sample was produced from a 60 meter section of nickel wire which had been used as an electrode in a potassium carbonate electrolytic cell. The wire was placed in an evacuated quartz tube and heated to 800°C, resulting in the outgassing of potassium and hydrogen loaded into the wire during electrolysis. The gas chromatography results showed the expected twin peaks associated with para and ortho hydrogen molecules for the control sample. For the sample from the quartz tube, the normal peaks were present along with additional intermediate lower level peaks, which were attributed by HPC to the presence of lower level hydrogen molecules. The gas chromatography results are relatively recent, and HPC is still developing the technique for this application, thus external review of the procedure and results has been limited to date. Nonetheless, these data lend additional weight to the evidence for the existence

of hydrino developed by XPS and mass spectroscopy.

As HPC has gained experience with procedures to detect the presence of hydrinos, the case for their presence on electrodes from the electrolytic cells, and in off-gases from both electrolytic and gas cells is gathering strength. HPC is working to expand the number of reputable scientific institutions working with the cells and conducting and refining procedures for hydrino identification as a means of developing widespread acceptance. Another procedure currently under consideration is to perform extreme ultraviolet/soft X-ray spectroscopy of emissions from an operating gas vapor cell. An established procedure for conducting spectroscopy under conditions and configurations similar to a gas vapor cell is said to be available, and is being investigated for use in conjunction with the vapor cell work currently under way at Penn State. If clear spectral lines consistent with hydrino transition energies are observed and found to correlate with the production of excess power, this procedure would provide definitive confirmation of the low energy hydrogen concept.

4.1.2 Hydrinos - Environmental Observations

Another argument for the existence of hydrino is based on observations of radiation spectra from space. Extremely large quantities of hydrogen are known to be present in interstellar space. Thus if the Mills theory is correct, evidence of hydrino formation in the form of soft X-ray emissions at wavelengths corresponding to the transition energies could be expected. However, to explain the quantities of hydrogen remaining in the universe given generally accepted values for the age of the universe, the transition probabilities must be low. This results in a relatively low strength signal for hydrino transitions. In addition, atmospheric attenuation is large in this region of the spectrum and background levels are high relative to expected signal strengths. Other potential sources of evidence of hydrino arising from more subtle effects, such as transitions in rotational energy among dihydrino molecules, would be found in other parts of the spectrum. HPC has been reviewing radiation data and seeking independent review and collaboration with astrophysicists with regard to evidence of the existence of hydrino.

In Ref. 16, spectral data taken by a sounding rocket, as reported in Ref. 21, were evaluated by HPC for indications of hydrino. Ref. 21 reported seven observed emission features in the wavelength range of 80 to 650 Å as shown in Table 4-1. In HPC's initial review of Ref. 21, peaks with wavelengths corresponding to transitions $n=1\rightarrow 1/2$, $1/2\rightarrow 1/3$ and $1/4\rightarrow 1/5$ were identified and assigned (Ref. 11), and the low signal-to-noise ratio of the data was stated as likely to have obscured the $1/3\rightarrow 1/4$ transition peak. HPC also reported in Ref. 11 that a review of the raw data obtained from the authors identified a possible additional peak which could be associated with the $1/3\rightarrow 1/4$ transition. Following external review and comment, and subsequent extension of the Mills model, including the development of the disproportionation reaction model, the emission energy from transitions was shifted by 54.4 ev, resulting in a reassignment of the lines to $n=1/3\rightarrow 1/4$, $1/4\rightarrow 1/5$ and $1/6\rightarrow 1/7$ transitions. The final assignments, as

documented in Ref. 16 are shown in Table 4-1. Several additional lines were identified in Ref. 16 from a review of the raw data and were assigned to other low energy hydrogen transitions plus related scattering and second order peaks.

Table 4-1 Extreme UV Interstellar Spectral Data

Observed Peak Wavelength, Å[1]	Labov & Bowyer Assignment[1]	Labov & Bowyer Wavelength, Å[1]	Mills Assignment[2]	Mills Wavelength[2]
$_{-5.3}98.7^{+4.2}$	Fe XVII, Fe XIX Log T=6.8	~99	1/6 - 1/7 Transition	101.3
$_{-4.6}178.1^{+5.1}$	Fe X, FeXI Log T=6.0	~178	1/4 - 1/5 Transition	182.3
$_{-4.4}200.4^{+5.3}$	Second Order 98.7 Line	~198	Second Order 1/6 - 1/7 Line	202.6
$_{-5.0}299.7^{+5.9}$	He II	304	1/3 - 1/4 Transition	303.9
$_{-4.5}582.1^{+4.5}$	He Scattering of Solar Radiation	584	He Resonance Scattered Emission	584
$_{-4.9}609.1^{+4.9}$	Second Order He II Line	609	Second Order 1/3 - 1/4 Line	607.8
$_{-4.7}634.7^{+4.7}$	O V 5.4<Log T<5.7	629.7	He Scattered 1/3 - 1/4 Line	633.0

1. Peak wavelengths determined from raw data by astrophysicists Labov and Bowyer, who conducted the experiment (Ref. 21), shown with 1σ confidence limits. These are the only peaks identified within the statistical analysis constraints used. Phenomena assignment and wavelengths developed in conjunction with determination of observed peaks.
2. Assignment of peaks identified in Ref. 21 by Mills based on transition energies for low energy hydrogen, (Ref. 16). Additional analysis of raw data obtained from Labov and Bowyer by Mills resulted in the conclusion that additional peaks were discernable that were associated with low energy hydrogen transitions.

It was concluded by HPC that the data were consistent with the presence of the lower energy hydrogen states predicted by the Mills theory, and that use of the Mills theory provides a more satisfactory explanation for the observed data than existing models. The comparison with the Labov and Bowyer peaks as assigned in their paper was identified by John Farrell (Section 5.2.5) as the strongest case for the existence of hydrino based on astrophysical evidence. The HPC interpretation of the data has been disputed by Bowyer, and the paper on the HPC interpretation submitted by Farrell, Mills and Good (Ref. 22) to Astrophysical Letters and Communications was not accepted for publication. Thus the low energy hydrogen concept and its implications regarding data interpretation has not received general review or acceptance by the astrophysics community.

More recent work by Mills has identified additional evidence of the existence of hydrino in astrophysics data. Spectral lines and characteristics of the sun have been associated with calculated hydrino transition energy levels, including dihydrino

molecule rotational transitions. The success of hydrino models in explaining observations heretofore not rationalized has begun to attract attention from astrophysicists. A proposed joint research project with the National Radio Astronomy Observatory is directed toward further exploring the validity of the Mills model in predicting radiation phenomena in space, as noted in the summary of a phone conversation with Dr. Barry Turner of the National Radio Astronomy Observatory in Section 5.1. It thus appears that the application of Mills theory to the explanation of observed phenomena in space is gaining some acceptance and credibility. However, as indicated by lack of acceptance of an earlier proposal (Ref. 23), the astrophysics community remains generally resistant to serious consideration of Mills' theory.

The correlation of the Labov and Bowyer extreme ultraviolet radiation study results with hydrino transition energies derived from Mills' theory is indeed striking. It is particularly noteworthy that the original identification of the spectral lines was conducted independently with no awareness of the Mills theory and its predictions regarding emission spectra. However, the complexity of interpretation of radiation data from space, in conjunction with the resistance in the astrophysics community noted above makes use of these data for assessing the validity of Mills' theory difficult. The absence of generally accepted support for the existence of low energy hydrogen among the astrophysical community is understandable given the revolutionary nature of the theory and the major revisions to longstanding interpretations of existing data which could result. For example, solar flare spectral observations proposed to be indications of a new element by Norman Lockyer in 1870 was not accepted as evidence of the existence of helium until 1895 (Ref. 24). If the low energy hydrogen reactions projected by Mills become proven and widely accepted, it can be expected that considerable attention will be given to reinterpretation of astrophysics data, and association of observed data with hydrino appears likely. However, in the current circumstances, and for the purposes of this assessment, the evidence for hydrino and excess power developed in the laboratory experiments is considered of greater value.

4.2 Prototype Performance

This section addresses the laboratory performances of cells constructed and operated in accordance with the HPC concept with regard to the case for the production of excess power (power beyond that which could be explained by conventional processes).

4.2.1 Water Based Electrolyte Cell (Low Temperature)

The 1990 cell reported in Ref. 9 was a small unit, utilizing a half liter container and 100 ml of electrolyte. The cell calorimetry was based on calibrating the thermal resistance for heat loss through what was designed to be a predominately conduction based heat transfer path to ambient. A resistance heater was included in the cell to support determination of the thermal resistance for cell heat loss, and the heater was also operated in conjunction with power to the electrodes in many of the cases.

"Excess power" was calculated by subtracting the difference between the cell energy losses:

- Heat transfer losses to ambient
- Water electrolysis energy

and the known cell energy inputs:

- Resistance heater power
- Power to cell electrodes

The quantities of energy losses and power input were small, ranging from a fraction of a watt to a few watts. Since the "excess power" was calculated as the difference among these quantities, the potential for measurement error or omitted or inadequately modeled phenomena resulting in misinterpretation of results is significant. This is common to all of the experiments of this nature, and provides the primary basis for controversy regarding the outcome of the experiments. A careful review of the cell description and results in Ref. 9 did not provide sufficient basis for a clear conclusion that excess power had in fact been observed.

The 1994 cell reported in Ref. 11 represented a considerable advance over the earlier cell. The larger size and increased power levels reduced measurement uncertainties, while the instrumented condenser provided for a direct measurement of cell heat loss. Thus the calibration runs constituted a check on the effectiveness of isolating the condenser as the dominant heat removal path, showing agreement between the input power and heat removal through the condenser. It was noted that during the electrolysis runs, an additional heat removal path was provided via vapor carryover and sensible heat loss from the effluent gases. This would result in an underestimate of the energy production in the cell and a corresponding underestimate in the cell excess power. The results from this experiment appear to provide a convincing case for excess power generation.

Independent confirmation of excess heat from electrolytic cells over long periods of time has been documented, including the following:

- V.C. Noninsky of the Laboratory for Electrochemistry of Renewed Electrode-Solution Interface, Sophia, Bulgaria, conducted H_2O/K_2CO_3 electrolyte/nickel electrode cell experiments as a visiting scholar at Franklin and Marshall College. He reported evidence of excess heat production in Ref. 25.
- Work was conducted at the Hokkaido University Catalysis Research Center in Japan to measure excess heat in H_2O/K_2CO_3 and H_2O/Na_2CO_3 cells using nickel, gold, silver and tin electrodes. Excess heat was reported for the H_2O/K_2CO_3 electrolyte/nickel electrode cell along with some of the other cells operated at the Center (Ref. 26 and 27).

- Additional measurements of excess heat in H_2O/K_2CO_3 electrolyte/nickel electrode cells has been reported (Ref. 28 and 29). However, while the experimenters reported excess heat, they believed that it was being generated by a fusion reaction with the alkali metals rather than the mechanism proposed by Mills.
- Engineers at the Moscow Power Engineering Institute reported excess energy produced "reliably and continuously over the last three months" (Ref. 30).
- In a report to Wright Laboratory of the Air Force Materials Command, Thermacore reported anomalous heat in a pressurized H_2O/K_2CO_3 cell with hydrogen gas introduced via a coil of nickel tubing (Ref. 31).
- A study at NASA Lewis Research Center (Ref. 32) identified apparent excess heat, but noted that the observations could be explained by recombination of electrolysis gases in the cell.
- Additional unpublished work at INEL, Westinghouse, and MIT Lincoln Laboratories (Ref. 33, 34, 35) indicate production of excess power.

While there has been a number of independent confirmations of excess power generation in the H_2O/K_2CO_3 electrolyte/nickel electrode cells, there has also been controversy regarding the source of the excess power. Other scientists continue to challenge the validity of the excess heat observations, most recently in Ref. 36. While the debate continues, the evidence of excess power generation in electrolytic cells based on the HPC concept identified in this assessment is convincing. Meanwhile, HPC has concluded that the electrolytic cells offer little commercial potential, and has moved on to gas cells as discussed below.

4.2.2 Gas Cells

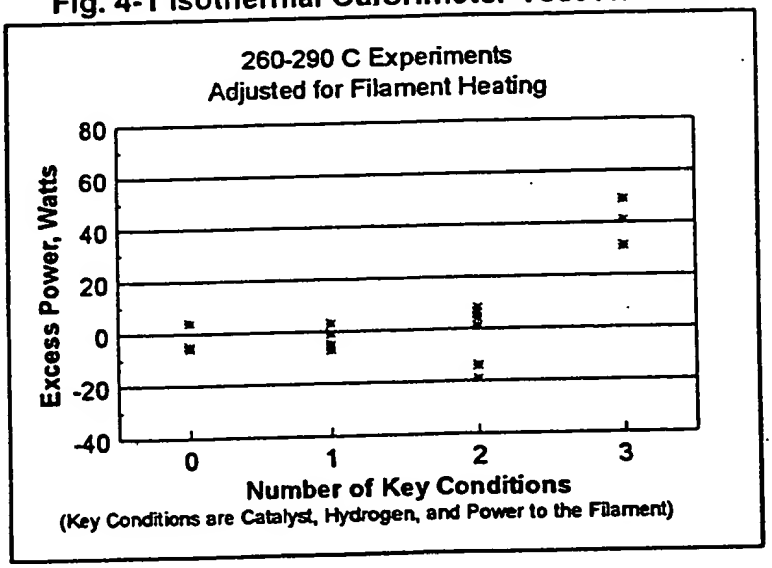
As illustrated in Sections 3.2, the gas cells are a recent development and have been undergoing rapid evolution from hydrogen diffusion/aqueous solution cells to solid state (sintered and spillover) catalyst cells to the most recent concepts, the vapor phase cells. Excess power production in the hydrogen diffusion/aqueous solution cell concept has been measured by Thermacore, as reported in Ref. 31. As noted in Section 3.2.2, testing of HPC cells at Penn State indicated excess power production by HPC sintered catalyst and spillover catalyst cells. Papers documenting these results were reviewed and the bases for the conclusions regarding the production of excess power were confirmed. However, most of the excess power review effort was directed toward the vapor phase cells, since they hold the most promise and are the focus of current HPC efforts to develop a commercially viable product.

The data obtained from HPC were reviewed and used to calculate the excess power values provided in Section 3.3 for the **At-Mar Glass Lamp** (Fig. 3-3) and the Isothermal Calorimeter cells (Fig. 3-5a,b). These tests are of limited accuracy and repeatability, as evidenced by the scatter in the data among the cases reported. For

the At-Mar Glass Lamp, heat losses out the top and by radiation to the water in the container are relatively uncontrolled. The silver plating on the internal surface of the inner quartz tube was a key factor in limiting radiant heat losses, and HPC noted that the silver appeared to be redistributing during the series of tests. Measurement of temperature inside the cell was difficult because the low pressure and predominance of radiant heat transfer made indicated temperature a strong function of thermocouple location relative to the filament. Thus cell temperature in the reaction zone, a key variable, was not well known or controlled. HPC addressed these limitations by conducting control tests with conditions as close to the active tests as possible. On balance, the overall results for the At-Mar Glass Lamp are considered to provide a statistically significant indication of excess power production.

The **Isothermal Calorimeter** is a relatively simple device where heat loss is assumed to be proportional to temperature, and the amount of input power required to bring the device to a given temperature is measured under various operating conditions. A reduction in the amount of input power required is an indication of excess power production. In reviewing the design of the Isothermal Calorimeter cell, a concern was identified regarding the measurement of temperature within the cell and its use to indicate heat loss from the cell. As illustrated in Figure 3-4, the thermocouple well was placed within the tungsten filament element. Under low pressure conditions with predominantly radiant heat transfer, heating of the thermocouple well by the filament could establish a significant temperature difference between the thermocouple well and the vessel wall. Since heat loss to ambient is a function of vessel wall temperature, this could result in a significant overestimate of heat loss to ambient and the corresponding excess power for cases where the filament is powered in comparison with cases where heat input to the cell is provided by the cartridge heater at the bottom. Data from HPC regarding the operation of the Isothermal Calorimeter provided support for the expectation that the thermocouple well would be hotter than the vessel wall when the filament was powered, and a basis for estimating the magnitude of the effect. These data were used to adjust the data for the filament heating effect, with results as shown in Fig. 4-1. In discussing this adjustment with HPC staff, it was agreed that this problem could be eliminated by placing thermocouples on the outside of the vessel, an approach HPC plans to take for future testing. While this adjustment reduces the excess power from about 60 Watts as

Fig. 4-1 Isothermal Calorimeter Test Results



indicated in Fig. 3-5b to about 40 Watts, there is still a clear indication of excess power production that correlates with the conditions required for excess power according to the HPC theory.

The **Calvet Calorimeter** cell is a much smaller device than the Isothermal Calorimeter cell, both in terms of physical size and range of input power. However, when placed inside an oven, it provides for better control of operating temperature and a much more accurate determination of thermal power production in the cell. It also provides a time dependent signal, indicating the time varying characteristics of the experiments, although short term variations in the reaction would not be detectable due to the long thermal time constant of the externally insulated thermopile. Since a continuous electrical output proportional to heat flow is generated by the thermopile, the signal can be used in conjunction with an input power signal from the power supply to calibrate the cell under control conditions. In the Penn State experiments, the filament power is produced by a highly accurate and stable constant power supply and the thermopile signal is zeroed out against the input power once steady state is reached in the absence of hydrogen. The input power is then held constant as hydrogen is introduced into the cell, allowing for a precise determination of the change in power production in the cell following the introduction of hydrogen. In the Penn State experiment in progress during the site visit, a fixed amount of hydrogen (the amount in the hydrogen container of Fig. 3-6) was available to the cell following opening of the valve to the hydrogen container. The indicated excess power slowly declined from an initial value of about 0.05 Watts to less than 0.01 Watts over a period of several days. This characteristic was consistent with a depletion of the hydrogen in the cell during the experiment. Initial analyses of the results are indicating excess power production on the order of 20 times that which would be generated by the hypothetical combustion of the hydrogen in the test cell. While the power level in the initial Penn State experiment was about a factor of 10 less than the power levels observed at HPC with operation at about 200 millitorr hydrogen pressure, the results could be quite significant from the standpoint of validation of the low energy hydrogen reaction. Atmospheric pressure operation of a vapor phase cell may be an effective way to produce sufficient quantities of gas to support more definitive experiments on the detection and characterization of hydrino. The vapor cell Calvet Calorimeter data being produced by HPC and Penn State provide strong support for the validity of the HPC concept, particularly in combination with earlier data produced by Penn State using sintered catalyst and spillover catalyst Calvet Calorimeter cells.

The **Metal Hydride Cell** has produced the highest power and the highest power density of any of the approaches to date. Measurements of cell pressure response as power is applied to the filament has confirmed the effectiveness of the hydrided wire as a source of hydrogen. This approach is an effective means for obtaining adequate hydrogen atom concentrations for testing and also for improving the understanding of the reaction process. It would not be a preferred process for general commercial application because of limits on the amount of hydrogen that can be stored and the resulting need to periodically replace metal hydride components as opposed to a continuous feed of hydrogen gas, and it could also exhibit performance degradation as

the stored hydrogen is depleted. However, it could have commercial potential in limited operation situations such as backup power applications. In the near term, it could serve an important role as a means of providing a convincing demonstration of excess power production.

The **Tungsten Powder Cell** is being developed as a means of obtaining high hydrogen atom concentration throughout the reaction cell volume. The tungsten powder provides a large surface area which can serve to dissociate hydrogen molecules when operating at elevated temperatures. Initial results were reported by HPC as indicating about 10 watts of excess power (about 10% of input power) from the device illustrated in Fig. 3-8 using 2.1 cubic centimeters of tungsten powder and operating at about 550°C. This concept is at a very early stage of development, and significant refinements and revisions to the device can be expected. For example, the initial device allowed communication between the outer region containing the heating element and the inner region containing the tungsten powder and catalyst compound. This raises a question as to where the reaction is taking place, since hydrogen around the filament will be dissociating and catalyst atoms could be present in the outer region. The device is being modified to seal off the inner region and provide a hydrogen and catalyst supply directly to the tungsten powder section of the inner region. With vibratory compacted powder as currently used, diffusion of hydrogen molecules and atoms, and of catalyst atoms through the powder may limit the power density. However, the use of a dispersed high surface area matrix of material which supports hydrogen dissociation when operated at elevated temperature is a likely avenue for development of an energy cell which could operate at sufficient power density and without electrical input to support commercial applications.

4.2.3 Vapor Phase Cell Development Status and Issues

HPC began working on the vapor phase cell concept in January, 1996. The vapor phase cell concepts are considerably simpler in their construction and operation than the earlier electrolytic cells, providing less room for errors and oversights as a basis for explanation of observed excess power. In addition, the amount of excess power production is increasing to a level that precludes instrument error as a possible explanation. Thus the vapor phase cells have the potential for providing a much more convincing case for the HPC concept than the earlier cells. Recent vapor cell results produced at HPC indicate a rapid advance in cell performance and production of excess power in each of several device configurations. Given these advances, HPC is concentrating on the gas vapor cell concept for testing and concept development.

Performance of HPC vapor phase cells, based on data obtained in the course of this assessment, is summarized in Table 4-1. Calculation of power density is relatively arbitrary because of the expected but not well characterized strong variation of reaction rates as a function of position within the cells. Thus three values for power density are given in the table. The first two assume a primary reaction zone within 1 or 2 mm of the hydrogen dissociation surface (filament) and calculate a power density based on the

DRAFT

resulting reaction volume. This approach is of more significance with regard to the development potential of the concept because devices can be designed such that the primary reaction zone encompasses most or all of the reaction chamber. The third value is an average power density based on the total volume of the test article, which is of less significance since it is a function of the design features of the test article rather than of the characteristics of the process.

Table 4-1 Power Density Estimate Comparisons

Cell Type	Volume, cc	Power, W	Power Density, W/cc*		
			Reaction Zone		
			1 mm	2 mm	Cell
At-Mar Lamp	150	2	4	1	0.013
Isothermal Calorimeter	2500	40	6.4	1.6	0.016
Calvet Calorimeter	20	0.5	1.6	0.4	0.025
Metal Hydride	30	120	15	7	4

* The temperature is known to vary substantially within the cell, affecting the catalyst atom density distribution due to localized production on hotter surfaces and plateout on colder surfaces, and the hydrogen atom distribution varies strongly with distance from the dissociation surface (e.g., filament) due to recombination to form molecules, thus reaction rate (power density) will be a strong function of location. The power densities shown are calculated assuming a primary reaction zone within 1 or 2mm from the dissociation surface, and a relatively arbitrary value assuming the entire cell volume as a reaction zone.

The progress achieved by HPC on the vapor phase cells, which have only been under development for seven months, is remarkable and indicative of the potential for advancement of this concept. Performance levels achieved at HPC during the past several months, if validated by the Calvet calorimetry work underway at Penn State, should be sufficient to provide a convincing case for excess power production. The primary thrust of current work at HPC is on advancing the concept toward devices that have commercial application potential.

The primary technical issues with regard to commercial application of the HydroCatalysis process are achieving adequate power density and controllability of the process. These issues are discussed below within the framework of the likely characteristics of the HPC process as understood from the information obtained. The HydroCatalysis device which would produce energy and transfer heat to an energy conversion system working fluid or heat exchange surface is referred to as the energy cell. Supporting auxiliary systems (e.g., hydrogen and catalyst feed systems) would have to be designed to support the steady state and dynamic requirements of the energy cell.

- **Power Density** - The power density achieved in the reaction section of the energy cells will drive the size of the cells as a function of output power. If high temperature operation is required, the material costs per unit volume of the energy cell may be considerable. The cost of fuel storage, handling and combustion equipment plus emission control systems of a fossil fueled system would be replaced with the cost of hydrogen production or storage systems plus the energy cell and supporting auxiliaries. The low to negligible fuel costs of the HydroCatalysis concept will support a premium in capital costs while remaining economically competitive, but energy cell reaction section power density will be a key factor in economic viability. As illustrated in Table 4-1, the power density obtained in cells operated to date is not well known because the spatial distribution of the reaction rate is not well characterized. From the overall data, power density in the range of 1 to 10 W/cc appears to have been achieved. Ideally, power densities in the range of other current energy systems (e.g., light water reactors,combustion turbines), on the order of 100 W/cc (see following section) would be desireable, but economic viability could probably be achieved at lower power densities. HPC projects a theoretical upper limit of power density of 55,000 W/cc, well beyond what is necessary or practically manageable. The disproportionation reaction mechanism postulated by HPC would enable multiple collapse of hydrogen atoms and a major increase in the energy production per atom, providing a plausible means of achieving the desired power density. A series of tests based on a preferred cell design and varying key parameters (e.g., hydrogen and catalyst atom density, temperature) to map out performance is needed to assess potential power densities and means of achieving them. The results to date are encouraging, given the limited time and resources expended on the vapor phase cell concept, but considerable work remains before a preferred cell design can be established and the needed tests conducted. In the interim, power density will remain a significant uncertainty.

- **Controllability** - The following discussion is based on an electric generation application, similar considerations would apply to heat or motive power applications.
  - **Startup** - The first aspect of controllability to consider is starting a system and achieving a stable initial operating mode for power operation. As currently envisioned, the energy cell reaction zone would have to be brought to an elevated temperature and the reaction process would be initiated and stabilized at a minimum self sustaining level by the introduction and control of hydrogen and catalyst atom densities. This would have to be achieved by the energy cell in coordination with the operation of the power conversion equipment, since some degree of heat removal from the energy cell will be required at minimum power to establish a stable operating temperature.

- **Power Operation** - Power operation would require the ability to achieve and maintain stable operation at any power level in the operating range, and to increase or decrease energy cell output power level with response characteristics as required by the energy conversion system for a range of normal operation and transient conditions (e.g., step load changes, component failures).
- **Shutdown** - Shutdown would include a range of conditions from slow decreases in power level to unit trips. The characteristics and requirements of the energy cell and supporting auxiliaries for decreasing or terminating power generation and cooling down would have to be integrated with the corresponding characteristics and requirements of the power conversion equipment.

If the energy cell is required to operate at high temperatures with ceramic components (e.g., thermal insulation), controlling cyclical thermal stresses to support an adequate design life may be a primary requirement driving system design. The dynamic response of the HydroCatalysis reaction and the thermal response of the energy cell will need to be well characterized to support modeling for control system design and system operation.

4.3 Applications and Projected Products

A systematic technology and market development process is needed to evolve HydroCatalysis technology to commercial practice. Such a process matches technology attributes with market opportunities to identify target markets for the mature technology, as well as with chances for early market penetration. A brief survey of energy industry applications was conducted to gain an initial impression of the market profile.

In a broad sense, HydroCatalysis offers a new fuel option to the energy industry. Its market acceptance will be enhanced if it can be utilized without a major re-tooling of power generation equipment. Ideally, the HydroCatalysis reactor (or a secondary heat transfer loop) would fit within the envelop currently required for the heat generation and transfer function. For example, a gas turbine combustor is the zone in which the fuel/air mixture is ignited and combusted before expansion through the power turbine. A potential HydroCatalysis reactor application is to replace the fuel combustor function. The space envelope for the combustor, expressed as power density, for commercial gas turbines is estimated to be in the range of 50 to 150 kilowatts per liter. As a further point of comparison, the power density of a boiling water reactor (ratio of reactor power to the volume of material inside the fuel cladding) was calculated to be about 200 kilowatts per liter. On this basis, a HydroCatalysis reactor power density in the vicinity of 100 kilowatts per liter is desirable, although a factor of 2 or so in either direction is probably acceptable.

DRAFT

Based on currently perceived HydroCatalysis reactor attributes, a likely initial target application is to replace the fuel combustor for powering gas turbines. For the past several years, gas turbine technology has been the focus of government and industry sponsored efforts to reduce pollutants and improve the utilization of coal and natural gas. In addition, several innovative small turbine concepts have recently been introduced in an anticipation of a new market in distributed generation assets. The merits of this application include:

- Gas turbines comprise over half of new generation sales and are proliferating rapidly in the global market.
- In the current cost and environmentally sensitive market, gas turbine concepts provide the lowest capital costs, and thermal efficiencies approaching 60% in combined cycle applications.
- The relative sophistication and temperature regime of advanced turbine systems appear to be compatible with the HydroCatalysis reactor interface, i.e., high temperature (in the vicinity of 1400°C) heat exchanger technology.
- Sizable markets exist for units in the range of a few hundred kW to a few MW, i.e., units sufficiently large to realize credits for pollution control advantages and to economically support auxiliary systems (e.g., hydrogen generation, reactor preheat and vacuum systems), yet within the range of a practical multiple unit beta testing program.

General Electric, Westinghouse, Allison Engine, and Caterpillar's Solar Turbines are all participants in separate DOE cost-shared (25%) advanced turbine development projects for natural gas-fired systems. In addition, Hague International is participating in an innovative concept called an "indirectly fired cycle" for coal-fired systems that employs a ceramic heat exchanger to protect the turbine from combustion gases. Such heat exchanger technology may be relevant to the HydroCatalysis reactor interface. Hague is constructing a 2-megawatt industrial-scale facility for testing the ceramic heat exchanger. Results will form the basis for a Clean Coal Technology project at Pennsylvania Electric Company's Warren Station.

Two other recent innovations in gas turbine technology are the Capstone Turbogenerator and the Solar Turbines' T-300 Gas Turbine Generator Set. Both are relatively efficient (30 and 40%), small (24 and 300 kWe), high speed (96,000 and 37,000 rpm, respectively) that employ directly coupled permanent magnet generators and state-of-the-art electronic power conversion technology. These attributes provide exceptionally compact machines, well suited to the distributed generation/cogeneration market. Their somewhat lower turbine inlet temperatures (~800°C) may offer a less demanding initial interface requirement for incorporation of a HydroCatalysis reactor.

Stirling engine applications were also briefly reviewed and several innovative concepts may eventually be enabled by successful development of the HydroCatalysis reactor. For example, the Stirling Technology Company (STC) has produced a 350

watt prototype device labeled the RG-350 RemoteGen™ and is developing 1 and 3 kWe devices. Their target market is remote telecommunications installations, off-grid homes and cogeneration applications. The reference design couples a free piston Stirling engine with a linear alternator to continuously supply 120 VAC or 12 VDC power. STC claims a 60,000-hour maintenance free life for their machines and have completed 23,000 hours of endurance testing on small functional prototypes. Although advanced energy storage or HydroCatalysis may someday enable such devices to be used in broad applications independent of a utility grid, such as in developing countries, they are relatively inefficient (~20%) and markets are not yet developed.

Of course, a wide spectrum of other potential applications exists and range from the Rankine cycle for electricity generation to the direct use of heat, and it is quite possible that further investigation will reveal premium niche applications for which HydroCatalysis is ideally qualified. Given its potential to bring about profound changes in the energy industry, a market for very early consideration is "functional demonstration units". Small units that can be used to display elementary heat generation from the HydroCatalysis process will be of interest to industrial product developers. A potential use of such devices is to acquaint the OEMs of industrial equipment with HydroCatalysis technology so that they can develop strategies for adapting product lines as a prelude to licensing agreements. Such devices may be in the size range of a few watts, need not be prototypic of a commercial product, and have minimal reliability and equipment interface requirements. They will command a substantial price premium, and the interactions with OEMs can be a source of early feedback to the HydroCatalysis reactor development program.

It is recommended that the HydroCatalysis development program proceed from the outset with the means to acquire and assimilate market information. In addition to identifying target markets to guide technical work and niche markets as a source of early revenue streams, knowledge of end-user needs relevant to process control and O&M is an essential aspect of defining technical design requirements and establishing cost/price targets.

4.4 Economics and Environmental Considerations

At a conceptual level, a process which obtains many times more energy per unit volume from water than is available from oil would be expected to have a major economic advantage over existing energy sources. Likewise, the absence of combustion products or other typical waste byproducts would be expected to represent a major environmental advantage. These prospects are addressed briefly in the following subsections.

4.4.1 Economics

The ability to extract considerably larger amounts of energy from hydrogen via the HPC process relative to conventional chemical processes is fundamental to the

economics. By illustration, assuming an average energy release of 100 electron-volts per hydrogen atom, the energy content of a standard cubic foot of hydrogen would be about 23,000 Btu/ft^3, in comparison with hydrogen energy content from the combustion process of about 340 Btu/ft^3. As another comparison, the net energy content of water would be about 30 times the energy content of gasoline. Thus the fuel costs for this concept would not contribute significantly to electricity generation costs, which would be determined by capital and operation and maintenance costs.

In their Business Summary (Ref. 7, pg. 55), HPC provided the following data on comparative electricity generation costs:

Table 4-2 HPC Comparative Cost Projections

Energy Source	Cost (¢/kWh)
Coal	4-5
Natural Gas	4-5
Oil	4-5
Nuclear	5-6
Hydroelectric	4-7
HydroCatalysis	**<1**

EPRI was cited as the source of the cost of competing energy sources, noting that the cost estimates did not include externalities. For the purposes of this study, a detailed review of these costs was not conducted; however, levelized life-cycle cost data from a recent Energy Information Administration paper (Ref. 37) were used for an approximate cost comparison. Only coal and natural gas were considered in the comparison since these options represent the dominant fuel forms of new generation capacity additions for the near future. Using the projections of levelized cost for the year 2000 in 1994 dollars for a capacity factor range of 60-100% and regional variations, the ranges shown in Table 4-2 were developed for coal and gas fired generation with fuel costs of about $1.25/MMBtu for steam coal and $2.20/MMBtu for natural gas. For the HydroCatalysis process, a combined cycle gas turbine configuration was assumed, consistent with the discussion in Section 4.3, with allowances for parasitic losses associated with electrolytic hydrogen generation (~5% of gross generation) and a reduction in cycle efficiency (due to reaction chamber material temperature limits) relative to a combustion turbine. These results are also shown in Table 4-2. In practice, steam methane reforming may be a more economic means of producing the hydrogen (Ref. 38) than the electrolysis process assumed above, but the difference in cost would not significantly affect the above results.

DRAFT

Table 4-3 Revised Comparative Cost Projections (Year 2000 Levelized Cost, 1994 $)	
Energy Source	Cost (¢/kWh)
Coal	4-5.5
Natural Gas	3-4
HydroCatalysis	**1.5-2**

In summary, while the cost advantage for the HPC process is likely to be less than projected by HPC, it is still substantial. Given the current total world electricity consumption, approaching 10^{13} kWh/year (Ref. 39), a projected market share of 33%, and a differential cost advantage of 2¢/kWh, a total of **$66 Billion/year** is obtained. This is considered to represent a reasonable projection of the potential value of the worldwide application of the HPC concept to the electrical sector. The preceding analysis does not consider the cost advantage of the HPC concept associated with externalities such as the environmental considerations discussed in the following section. Policy development efforts to quantify and assess the costs of these externalities are continuing (Ref. 40), and could result in an additional cost advantage approaching the 2¢/kWh noted above.

4.4.2 Environmental Considerations

The quantities of water consumption, and oxygen and hydrino production for a 1000 MWe HydroCatalysis based multi unit combined cycle gas turbine plant were estimated, with assumptions and results as shown in Table 4-3 below.

Table 4-4 HPC CCGT Plant Characterization	
Description	**Value**
Plant Capacity	1000 MWe
Net Thermal Efficiency	45 %
H_2 Energy Release, Avg	100 ev/H atom
Water Consumption	47,500 gallons/day
Oxygen Production	176 tons/day

The above values are based on multiple fractional quantum state hydrogen transitions taking place in the reactor such that on average 100 ev of energy is released per hydrogen atom produced for fuel. The actual average amount of energy per hydrogen atom is not known at present, since it is a function of the degree of collapse before the

reaction is terminated by the formation of a dihydrino molecule. The disproportionation mechanism could drive the reaction to lower levels of collapse, and much larger energy releases. Hydrogen production by electrolysis with an 80% efficiency of energy usage is assumed, with 5% of the gross generation being used in the electrolysis process. The net thermal efficiency of 45% includes this 5% loss, along with an allowance for a lower efficiency for the gas turbine relative to the best combined cycle units being deployed today because the temperatures are assumed to be lower than combustion turbine temperatures due to the need for a heat exchange surface between the HPC reaction gas and the air.

The environmental factors associated with coal-fired, gas-fired, and projected HydroCatalysis based generation are compared in Table 4-4 below.

Table 4-5 Electricity Generation Environmental Release Comparison

	Fuel Production	Fuel Transportation	Generation
Coal	NO_x, CO_x, SO_x, particulates, hydrocarbons	NO_x, CO_x, SO_x, particulates, hydrocarbons	NO_x, CO_x, SO_x, particulates, hydrocarbons
Natural Gas	hydrocarbons	NO_x, CO_x, hydrocarbons	NO_x, CO_x, hydrocarbons;
HydroCatalysis	oxygen		NO_x, hydrino

The shaded columns of the above table are intended to indicate the degree of significance of the release, with darker shading indicating greater significance. The releases from the coal and natural gas fueled generation noted are generally understood and will not be discussed further here. The HPC gas cell requires hydrogen as a fuel, resulting in the release of oxygen during the production of hydrogen from water feedstock. Oxygen is currently a marketable commodity, however, the quantities produced by a substantial penetration of the electricity generation market by HydroCatalysis would be expected to greatly exceed demand, resulting in release to the environment. The release of oxygen could be a net environmental benefit, replacing some of the oxygen source lost by the depletion of the tropical rain forests, although the magnitude of the release from the HydroCatalysis would be considerably smaller. For the gas turbine configuration, NO_x production is expected to occur in the high temperature zone around and downstream of the HydroCatalysis heat exchanger. As indicated in the above table, the effluents from the HydroCatalysis process would be much less detrimental to the environment than the primary existing options for power generation.

Despite the apparently benign characteristics of the HPC process, it is conceivable that some opposition could arise due to the permanent consumption of water in the production of hydrogen. An estimate was made of the water consumption assuming the HPC process was producing 33% of the current total world electricity

consumption with operating parameters consistent with Table 4-3. This resulted in an annual water consumption of 6.6×10^9 gallons of water consumed per year. While this appears to be a significant quantity, it would take **370,000 years at this rate to consume an inch of water from the oceans.**

5.0 Telephone Interviews and Site Visits

A number of telephone interviews and site visits were conducted in the course of this assessment. The perspectives and information gained through these discussions are reflected in the information and assessment provided in the earlier sections. The individuals and organizations contacted and the information obtained is summarized in the following sections.

5.1 Telephone Interviews

Telephone interviews are grouped in the following areas: (1) General Background, (2) Theory and Hydrino Validation, and (3) Excess Power Evidence. The interviews are summarized in the following subsections.

5.1.1 General Background

- **Tom Passell, EPRI** (Ref. 41) - As Manager, Deuterated Metals Research Program, Passell has managed EPRI research involving cold fusion and other related areas. Passell noted that EPRI had spent about $10 million in cold fusion related research, and has confirmed that excess heat is present in some cases, but hasn't confirmed the source of the heat. EPRI's primary contractor, SRI, has not seen any positive results from light water, but they had not expected to see anything so they have not done much in that area. Passell had visited HPC and Thermacore (where an HPC cell was operating) in 1992, and felt there were considerable uncertainties in the cell configuration they were operating at the time. EPRI had funded an attempt to replicate the Mills process at AECL's Chalk River Laboratories, which was unsuccessful in demonstrating excess energy in Passell's view. He noted that HPC and Chalk River were involved in litigation regarding the content and distribution of the final report. Overall, Passell felt there remains a possibility that the HPC process is generating excess energy, but expressed reservations about HPC's strong convictions regarding the validity of the theory, which he felt could be affecting the interpretation of their data. The EPRI program budget for 1996 is $200 K, including Passell's labor and expenses (Passell is now working half time), leaving about $100 K for outside work. Their current focus is on identification of nuclear species from cell electrodes using neutron activation analysis, assuming some sort of fusion reaction is responsible for the excess heat. Passell noted that Ernest Criddle

of Ottawa University had been studying the HPC cell and would be a good source of additional information.

- **Ernest E. Criddle, formerly Ottawa University** (Ref. 42) - As noted above, Dr. Criddle was recommended as a reference by Tom Passell of EPRI. Dr. Criddle has retired from Ottawa University, but has maintained an interest and involvement in HPC type electrolytic cells through his work with ESCO Energy Inc., a spinoff of the university. He noted that he believes something is going on with the cells, but he hasn't been able to figure it out, and has had trouble getting repeatability. He also noted that he was visited several years ago by Randy Mills and Bill Good of HPC, and that they have techniques about preparing and filling the cell which are critical to performance, and are not related to "textbook chemistry". He was unaware that HPC is now focusing on a gas cell, but said he is convinced that a gas cell is the way to go with the process, because it eliminates the chemical complexities of the electrolysis process in the liquid cell.

- **George H. East, Stone & Webster Engineering Corp.** (Ref. 43) - Dr. East's name was provided by Mills as a reference for current interactions between HPC and SWEC. He said SWEC involvement began last fall with a visit to SWEC by Mills, followed by a SWEC visit to HPC. He said they have executed a confidentiality agreement with HPC, but that their work was on a minor level, having reviewed published papers and documentation obtained from HPC, but not having seen HPC's recent gas cells or audited their performance, and having limited knowledge of the details. They have been working with HPC on an unfunded basis to provide support regarding boiler options and energy conversion equipment. At this point, SWEC is interested in the concept, but are not sure how it's going to go, noting that the theory is controversial and that they would like to see more independent confirming results.

- **Dick Mulik, Westinghouse** (Ref. 44) - Dr. Mulik is coordinating an assessment of HPC for the Westinghouse Science & Technology Center (STC). Mulik noted that Westinghouse "has been putting in some real money" into a program at STC this year, which is intended to reach a definitive conclusion regarding the HPC theory and low energy hydrogen. Westinghouse has been dealing with HPC on and off for the past several years, having done an in-house experiment several years ago which they considered to be inconclusive. No experimental work related to HPC is currently being performed within Westinghouse, but the current assessment is looking at both the theoretical and experimental aspects of HPC's work. Mulik noted that if they find the theory to be incorrect, they're going to have to come up with some other explanation for the experimental results (implying a conviction that something unusual is occurring). He said it would be premature to make any comment regarding Westinghouse's view of the technology at this point.

Mulik, along with Art Beyers of Westinghouse STC and Rex Ramsier of Westinghouse Bettis Atomic Power Laboratory visited Penn State on the same day as the TI visit (addressed in Section 5.2.3). Mulik stated that there is high level interest at Westinghouse, and that STC has until the end of the year to reach a definitive position regarding the HPC process. Ramsier said that the head of Naval Reactors had received a letter regarding the HPC process, which was the basis for Ramsier's participation in the review. He noted that he had attended a seminar at STC given by Mills in 1994, and that his trip report had raised some interest at Bettis at the time and caused him to be identified with the subject. All of the Westinghouse reviewers were skeptical of the Mills theory and unconvinced of the existence of hydrino from their review of the data. They were interested in measuring the thermal conductivity of the off-gas from a cell, expecting that hydrino would have higher thermal conductivity than hydrogen. They intend to work with Mills and Phillips of Penn State to plan and conduct thermal conductivity measurements (Mills had earlier expressed skepticism that this approach will be successful because of the quantities of hydrino gas required). Phillips agreed to collaborate with Westinghouse on performing the measurements, with the understanding that the work would be done in close collaboration with HPC.

5.1.2 Theory and Hydrino Validation

- **Stewart Kurtz, Pennsylvania State University** (Ref. 45) - Dr. Kurtz is Professor of Electrical Engineering and Vice Chair of the Materials Research Institute at Penn State. He has an industrial research background, having worked at Bell Laboratories for 10 years, served as Director of Research at Philips Electronics, and as VP, Engineering at Bristol Meyers before joining the faculty at Penn State. He became involved with the HPC concept about five years ago, when he met with Mills in Lancaster, PA as Assistant Director of the Materials Research Institute. He has been working to understand and challenge Mills' theoretical work since that time. He has involved a number of physicists in his review of the theory, and each of them have raised objections which have been addressed by further development of the theory. These challenges have resulted in substantial growth in Mills' book from the earlier versions to the current version. He also contacted H. A. Haus of MIT, who developed much of the mathematical formalism underlying Mills' theory (Ref. 46) and requested that he review the theory. Haus said the mathematics were correct, but he could not support the physics because it is not adequately supported by data. At this point, Kurtz believes HPC has demonstrated excess heat with reproducibility, and they need to develop more data regarding the presence of hydrino to provide complete confirmation. He has been talking with Mills and Jonathan Phillips about experimental procedures that could provide sufficient proof of the existence of hydrino.

Kurtz also said that he had followed the Thermacore involvement with HPC in the development of the concept. He had high regard for Yale Eastman, the founder of Thermacore, and for his company, noting that Eastman had invested several hundred thousand dollars in independent confirmation of the excess heat and development of potential commercial applications. Thermacore had demonstrated excess heat, but were unable to identify a commercial application for the devices they were working on.

- **Barry Turner, National Radio Astronomy Observatory** (Ref. 47) - Dr. Turner has been working with HPC regarding the potential for confirmation of the existence of hydrino via astrophysical data. He has been working with HPC on the development of a proposal to search for evidence of hydrino using an NRAO radio telescope (Ref. 48). Turner said that Mills has a case for looking further for astrophysical evidence, but not a compelling one. He said that some of the spectral lines have been "flat out misidentified" in earlier HPC documents, but there are enough questions left over to be of interest. A search of the type being proposed is very difficult because the frequency region to be scanned has to be identified accurately. Due to the high resolution required, a small frequency range has to be identified to limit the telescope time required. On the whole, Turner believes it is unlikely that the search will shed new light because they can't calculate the energies of hydrino hyperfine splitting accurately. In addition, the kind of gas that would be detectable as containing hydrino would also emit recombination lines. Although the recombination lines could be calculated precisely, they would take up about 15% of the spectrum in the region of interest (~29 GHz) and thus would require extensive calculations to assure that lines that might be assigned to hydrino were not recombination lines. A failure to confirm the existence of hydrino by the experiment would not be very significant because it would be very difficult to obtain a strong positive result. However, the range of spectrum being considered has never been searched, and given the importance of a positive outcome, he thinks it should be done.

  Turner said that an earlier proposal (Ref. 48) based on part on the HPC interpretation of the Labov and Bowyer paper (Ref. 21) had not been successful. In the review of the proposal, the referees had focused on the proposal's interpretation of the Labov and Bowyer data, and concluded that the original interpretation of the data by Labov and Bowyer is correct. From his review of the communications and the paper, Turner said he agrees with the referees, and believes that a revised proposal with fewer lines cited would have a better chance. He noted that diffuse X-ray spectroscopy is not an easy thing to do, and he would not be surprised if not all of the lines expected from hydrino transitions are present. He hopes to get additional support from Mills in the form of calculation of hydrino collision probabilities as input to preparation of a revised proposal in August for telescope time during the coming winter. He noted that the telescope to be used will be shut

down after one more year, so this would be the last chance at conducting the experiment as proposed.

- **Reinhart Engelmann, Oregon Graduate Institute of Science & Technology (OGI)** (Ref. 49) - Dr. Engelmann is a member of the faculty of the Department of Electrical Engineering and Applied Physics at OGI, currently on a leave of absence. He received a degree in Nuclear Physics from the Technical University in Munich, Germany in 1961, and his current research interests include modeling and design of solid-state photonic devices: quantum well lasers and optical waveguides. Engelmann documented a review of Mills' second book, Unification of Spacetime, the Forces, Matter, and Energy (Ref. 50), and has been following Mills' progress for several years (he is a member of the HPC Science Advisory Board). Engelmann's perception is that Mills works on a highly intuitive scale, then once he has an intuitive picture, he tries to wrap it into a mathematical description.

  Engelmann said he has a very strong feeling that Mills has proper ideas, particularly regarding the low energy forms of hydrogen. However, he is not completely in agreement with everything that Mills had done in developing the theory from a mathematic point of view. He said one of the problems is that Mills presents information in a form physicists are not used to, and that although he has worked closely with Mills, he cannot follow everything. He believes there are some inconsistencies in the theoretical framework, noting treatment of the Dirac δ function in spherical coordinates, and conclusions regarding the Heisenberg Uncertainty Principle as examples of his concerns. He feels that what is needed is for others to become interested and begin working on it, and believes that the best way to make that happen is to advance an energy generation device and expand the empirical evidence supporting the theory. He noted that he had visited Mills at HPC in early 1995 and again in April, 1996, and was very impressed with what had been accomplished in advancing the cells during that period.

5.1.3 Excess Power Evidence

- **Michael G. Jacox, INEL** (Ref. 51) - Michael Jacox was identified in a list of references provided by HPC in conjunction with work done at INEL in 1992 with regard to independent confirmation of excess heat from an HPC cell. He was contacted as an audit check on the list of references. Jacox was located in Albuquerque, where he is currently on assignment with the Air Force on an unrelated project. He was surprised that I was asking him about the results of his work, in that the paper describing the results was never approved for release by INEL management. However, he said he stands by the results of the work, and believes that he did get positive results regarding the release of excess heat in the cell.

- **Bob Shaubach, formerly Thermacore** (Ref. 52) - Shaubach left Thermacore in 1995, having worked on the HPC theory and technology since 1992. On of the first experiments performed by Thermacore was the operation of an electrolytic cell obtained from HPC that was reported by HPC to have produced 50 watts of excess power. Thermacore did observe 50 watts of excess power from the cell, in one case with only 5 watts of input power in a pulsed mode. Shaubach was also involved in the conduct of experiments using hydrogen permeation through nickel tubing and nickel powder permeated with hydrogen. All the experiments demonstrated excess power, but did not provide a basis for a commercial application. Shaubach has not kept up with the evolution of the HPC cells, so was unaware of recent developments.

- **Nelson Gernert, Thermacore** (Ref. 53) - Gernert was the project engineer on the experiments conducted by Thermacore relative to Mills' theory. He noted that they had conducted experiments with electrolytic cells, hydrogen diffusion through nickel tubing, and hydrogen permeated metal powder, and they saw excess power in all cases. He said they didn't see anything that would be inconsistent with Mills' theory, and he is convinced that they were seeing excess power. However, after several years of trying different approaches, they were unable to get the power density up to a level which would be sufficient for commercial applications. Thermacore is currently putting a high priority on developing volume manufacturing capability for heat pipe cooling devices for laptop computers, and hasn't been actively pursuing the HPC concept for several months. Some of their cells have been loaned to HPC for interim use. Thermacore expects to get the cells back, and would be interested in taking another look if HPC makes progress on increasing the power density.

5.2 Site Visits

5.2.1 HydroCatalysis Power Corporation

A visit to the HydroCatalysis Power Corporation offices was conducted on June 17-18, 1996. Prior to the visit, Technology Insights executed a confidentiality agreement with HPC to allow access to recent data and internal HPC documents. Much of the visit was spent in discussions with Mills regarding the theoretical basis for their concept and the experimental evidence for excess heat and hydrino. These discussions served to strengthen TI's understanding of these areas, and are reflected in the respective sections of this report. A tour of the laboratory area of the HPC offices was conducted by Bill Good, and included operating cells representing the most recent gas cell concept. A particularly striking element of the current cells is their simplicity as indicated by the relatively small number of connections (tubing, instrument and power leads) to the cells and by drawings of the cell internals. This characteristic

should be of significant value both in demonstrating the validity of the concept and in translating the concept into practical applications.

HPC was visited again on July 2-3, 1996 in conjunction with a meeting to discuss the results of TI's initial review and arrive at an agreement for a standstill period for further due diligence review and venture development. Prior to the meeting, the current experimental work being conducted in the HPC lab was reviewed with Bill Good, and data produced by recent vapor cell experiments were obtained. The initial results of a TI review of these data was discussed with Bill Good at HPC on July 17, 1996 in conjunction with a round of visits to supporting university laboratories. Activities in the HPC laboratory were again observed, including initial operation of a higher temperature cell utilizing a tungsten powder concept. The results of the HPC visits are reflected in the discussions of the technology provided in other sections of this report.

5.2.2 NovaTech

NovaTech is a small (currently 7 professional employees) engineering and technical services company located in Lynchburg, Virginia, and made up primarily of former Babcock & Wilcox engineers. NovaTech has been identified by HPC as a potential engineering arm to provide design, fabrication and testing services for the development of an energy cell to be used in a prototype unit. Since several key NovaTech personnel are currently on assignment in California, a meeting was held in the Los Angeles area to discuss NovaTech capabilities and interests relevant to the HPC concept. NovaTech representatives at the meeting included Richard Rochow, President; Lew Walton, Director of Business Development; and Barry Miller.

NovaTech has experience that is directly applicable to the HPC gas cell concept, and appears well qualified to support the evolution of the cell design. As an engineering contractor on the Air Force Space Nuclear Thermal Propulsion (SNTP) project, they provided design and testing support services for high temperature, high power devices utilizing hydrogen. Design capabilities include mechanical design, structural analysis, thermo-hydraulic analysis, materiels and systems engineering. They also have fabrication and testing experience with devices at temperatures and with system complexities that would envelope the anticipated HPC cell development.

NovaTech has had interactions with HPC going back several years, and has a good understanding of the concept and its primary characteristics. In 1994 they developed and presented a proposal to HPC for a systematic exploration of the variables associated with the electrolytic cells to achieve an economically viable level of performance. That proposal was not funded, but in 1996 NovaTech has performed internally funded work pursuing the gas vapor cell concept. The work was conducted under limited funding and time constraints, and has not succeeded in producing measureable excess power. They believe the negative results may have been due to shortcomings in their procedures, but have suspended further work to address other

commitments. (Subsequent telephone discussions with NovaTech personnel indicated that they may have seen a small (~1.5% of input power) amount of excess power in an experiment conducted in early July.) NovaTech recently submitted a proposal to HPC to design, fabricate and operate a vapor cell which could provide for a systematic and controlled variation in key parameters (e.g., temperature, hydrogen pressure, catalyst pressure). They expressed reservations about the validity of Mills' theory, particularly with regard to modeling of the universe. However, they are confident that excess power has been produced in HPC cells, and are motivated to participate in the development of the concept.

5.2.3 Pennsylvania State University

Dr. Jonathan Phillips of the Penn State Chemical Engineering Department has been conducting calorimetry experiments on HPC cells utilizing a catalyst and flowing hydrogen. TI met with Dr. Phillips on July 15-16, 1996. Representatives from Westinghouse were also visiting Dr. Phillips' lab on July 16, and participated in the lab tour and subsequent discussions. The Westinghouse participants and their intended future actions are discussed in Section 5.1 in the context of an earlier phone conversation with Dick Mulik of Westinghouse.

Phillips has been developing and working with precision micro calorimeters and developing catalytic processes for the past four years in areas unrelated to HPC, and is increasingly recognized as an authority in the field. His work with the HPC cells utilizes thermopile based calorimeters capable of accurately measuring changes in power of less than 0.01 watt relative to an established baseline. He has filed declarations in support of HPC patents based on early work with HPC cells (Ref. 54). Recent results from spillover catalyst cells designed and fabricated in collaboration with HPC and operated by Phillips demonstrated energy releases well in excess of known chemical processes (Ref. 15).

Dr. Phillips is well qualified for performing work on the HPC cells directed toward identifying and quantifying excess power generation. He has a strong personal interest in the technology, and has contributed significant amounts of time and discretionary resources to studying cell performance. However, he has taken a low key approach to working with HPC in light of the negative environment within the academic community surrounding any work which could be perceived as "cold fusion" related. A brief tour of the Chemical Engineering Laboratory and review of other experiments being conducted by Phillips and supported graduate students was confirming of positive impressions regarding his capabilities gained from initial discussions.

Testing of the HPC vapor cell concept is at the very early stages, having begun in mid-July, 1996. The first test was underway during the site visit, with initial results indicating excess power was being produced. In a phone conversation subsequent to the visit, Phillips said that their initial analysis indicated total energy generation in the cell equivalent to about 20 times that which would result from combustion of hydrogen

given the hypothetical presence of oxygen (confirmed by TI based on observations made during the visit). This first test was operated at near atmospheric pressure, far above the approximately 1 torr (1/760th of an atmosphere) of primary interest to HPC. While this was the result of a miscommunication between Phillips and the graduate student conducting the work, Phillips noted that he likes to approach the early runs in an experiment in a somewhat random fashion because the results aren't always as expected, and information can be gained by not focusing the testing too early. Operating the cell at near atmospheric pressure has produced results which indicate energy generation at a level detectable by the highly sensitive calorimeter developed by Phillips. While these results may not be very useful in the optimization of an energy production device, they may point to a means of efficiently producing hydrino gas predominately composed of $n=^1/_2$ atoms. This may significantly accelerate the process of obtaining results which will support the broad acceptance of the existence of low energy hydrogen.

5.2.4 Lehigh University

Dr. Albert Miller of the Zettlemoyer Center for Surface Studies at Lehigh University has been conducting X-ray Photoelectron Scattering (XPS) measurements on nickel cathodes from electrolysis cells provided by HPC, and a carbon cathode from a cell operated at Lehigh. As noted earlier, the XPS data are considered by HPC to be important evidence of the existence of hydrino. Miller discussed the difficulty of using XPS for identification of hydrogen or any material similar to hydrogen because of the small cross section for photon interaction (on a normalized scale where the cross section of carbon is 1.0, the cross section of hydrogen is 0.0002). Assuming hydrino has a cross section similar to or less than hydrogen, substantial quantities would be required to obtain a signal, and very small fractional quantities of impurities, or secondary peaks from other materials present (i.e., potassium), could produce a signal which would mask or be mistaken for hydrino. HPC maintains that iron is the primary impurity which could produce a peak in the region of 55 ev, where a hydrino peak would be expected, and since iron has been shown not to be present by other means (TOF-SIMS), the observed peaks are assigned to hydrino. Miller believes the results of experiments to date neither prove nor disprove the existence of hydrino, because low level impurities in the electrode or the electrolyte which could be concentrated at the cathode surface during the electrolysis process, or secondary peaks of potassium could produce the feature assigned to hydrino by HPC.

Dr. Miller believes that definitive results regarding the existence of hydrino could be obtained from a gas phase XPS experiment. This experiment would flow off-gas from an HPC cell, which would be expected to contain hydrino and may be processed to enrich the hydrino content, through an XPS instrument. Miller expects that such an experiment would require about a half liter of gas (~ 10% or greater hydrino). The total scope of the experiment, including producing baseline results on pure hydrogen and other samples as appropriate, is estimated to take between three and six months and cost between $100,000 and $200,000.

5.2.5 Franklin and Marshall College

As noted previously, Dr. John Farrell of the Chemistry Department of Franklin and Marshall College was an early collaborator with Mills in the development of the theoretical basis for the HPC concept (Ref. 3). Franklin and Marshall is a small (~1800 students), private liberal arts college located in Lancaster, PA. Mills attended Franklin and Marshall, receiving a BA in Chemistry in 1982. Farrell said Mills was widely recognized as an exceptional student, and typically presented a strong intellectual challenge to the faculty in the courses he took, asking difficult questions based on an in-depth fundamental understanding. After obtaining a M.D. from Harvard in 1986, Mills received support from Franklin and Marshall in the form of equipment and laboratory space to pursue development of medical technology devices. The initial development of Mills' quantum mechanics theory took place during this time, leading to publication of the initial book (Ref. 3) on the subject.

In the course of discussions at HPC in conjunction with this review, Mills had identified Farrell for follow-up regarding the astrophysics data supporting the existence of hydrino. Farrell said he believes the strongest evidence from astrophysics comes from the paper by Labov and Bowyer (Ref. 21). The paper was found by Bill Good in a literature search for astrophysics evidence of the existence of hydrino. In this case, the spectral lines had been identified from the raw data by the authors, and were in excellent agreement with the expected lines from hydrino transitions (see Table 4-1). Farrell said that a paper documenting the matching of the Labov and Bowyer results with low energy hydrogen emission spectra was submitted to Astrophysical Letters and Communications (Ref. 22), a companion publication to the Astrophysics Journal which published the Labov and Bowyer results, but the paper was not accepted for publication. Farrell expressed frustration at the unwillingness of the leaders of the astrophysics community to consider alternative interpretations of observed data. However, Farrell felt the other astrophysical data comparisons (e.g., solar flare data) were based on direct interpretation of the raw data, which requires a sophisticated level of understanding of statistical applications in astrophysics, and thus are of lesser confidence than using the original Labov and Bowyer data interpretation.

Farrell is a member of the HPC Science Advisory Board as well as a shareholder in HPC. Some of the early confirmatory work replicating HPC electrolytic cells was performed at Franklin and Marshall (Ref. 25), but no work is being conducted at present in support of HPC. Farrell noted that two other members of the Chemistry Department at F&M hold HPC shares, indicating the degree of support for the concept. Farrell also noted that two members of the F&M Physics Department have been following the development and validation of Mills' theory.

DRAFT

6.0 References

1. FAX: C. N. Winningstad to Fred Buckman, "RE: New Paradigm for Utilities", May 13, 1996.

2. Technology Insights, "HydroCatalysis Power Corp. Assessment", July, 1996.

3. R. L. Mills and J. J. Farrell, The Grand Unified Theory, Science Press (1989).

4. E. Storms and C. Talcott, Proceedings of Workshop on Cold Fusion Phenomena, Santa Fe, NM, May 23-25, 1989.

5. S. Jones, et. al., "Observation of Cold Nuclear Fusion in Condensed Matter", *Nature, 338, 737, (1989).*

6. M. Fleischmann, S. Pons and M. Hawkings, "Electrochemically Induced Nuclear Fusion of Deuterium", J. Electroanalytical Chem., **261**, 301 (1989).

7. HydroCatalysis Power Corporation, "Business Summary" (1996).

8. N. V. Sidgwick, The Chemical Elements and Their Compounds, Volume I, Oxford, Clarendon Press, (1950), p. 17.

9. R. L. Mills and S. P. Kneizys, "Excess Heat Production by the Electrolysis of an Aqueous Potassium Carbonate Electrolyte and the Implications for Cold Fusion", Fusion Technol., **20**, 65-81, (1991).

10. R. L. Mills, W. R. Good and R. M. Shaubach, "Dihydrino Molecule Identification", Fusion Technology, **25**, 103, (1994).

11. R. L. Mills and W. R. Good, "Fractional Quantum Energy Levels of Hydrogen", Fusion Technol., **28**, 1697-1719, (1995).

12. N. J. Gernert, R. M. Shaubach, "Nascent Hydrogen: an Energy Source", SBIR Phase I Project, Sponsored by Wright-Patterson AFB, Report 11-1124, March, 1994.

13. Bradford, M.C.; Phillips, J.; "A Calorimetric Investigation of the Reaction of Hydrogen with Sample PSU #1", Report to HPC, (1994).

14. Phillips, Jonathan; Shim, Hyunsip; "Additional Calorimetric Examples of Anomalous Heat from Physical Mixture of K/Carbon and Pd/Carbon", Report to HPC (1996).

15. Phillips, Jonathan, "Additional Examples of Anomalous Heat: Hydrogen Mass Balance", Report to HPC (1996).

16. R. L. Mills, The Grand Unified Theory of Classical Quantum Mechanics, (1995)

17. R. L. Mills, Unification of Spacetime, the Forces, Matter, and Energy, Science Press (1992).

18. Letter, R. Engelmann to R. Mills, Review of Unification of spacetime, the Forces, Matter, and Energy, June 3, 1994.

19. Mills, R., et.al., "Fractional Quantum Energy Levels of Hydrogen, Representative Recent Results, Prepared for PacifiCorp 7/3/96", (1996)

20. Mills, R. "Identification of Hydrinos--Hydrogen Atoms in Fractional Quantum Energy Levels--by XPS (X-ray Photoelectron Spectroscopy)", (1996)

21. S. Labov and S. Bowyer, "Spectral Observations of the Extreme Ultraviolet Background", The Astrophysics Journal, 371, 810, (1991).

22. Farrell, J.; Mills, R.; Good W.; "An Alternative Explanation of Extreme Ultraviolet Emissions from Dark Matter", Submitted for Publication to Astrophysical Letters and Communications (1993).

23. Mills, R.; Kurtz, S.; Turner, B.; "A Search for Hydrino - A New Form of Hydrogen". (1995)

24. New Scientist Forum, "Happy Birthday, Helium", April, 1995.

25. V. C. Noninski, "Excess Heat During the Electrolysis of a Light Water Solution of K_2CO_3 with a Nickel Cathode", Fusion Technology, 21, 163 (1992).

26. R. Notoya, "Cold Fusion by Electrolysis in a Light Water-Potassium Carbonate Solution with a Nickel Electrode", Fusion Technology, 24, 202 (1993).

27. T. Ohmori, M. Enyo, "Excess Heat Evolution During Electrolysis of H_2O with Nickel, Gold, Silver, and Tin Cathodes", Fusion Technology, 24, 293 (1993).

28. R. T. Bush, "A Light Water Excess Heat Reaction Suggests that 'Cold Fusion' May Be 'Alkali-Hydrogen' Fusion", Fusion Technology, 21, 163 (1992).

29. M. Shrinvasan, et.al., "Tritium and Excess Heat Generation During Electrolysis of Aqueous Solutions of Alkali Salts with Nickel Cathode", 3rd Annual Conference on Cold Fusion (1992).

30. S. B. Nesterov, A. P. Kryukov, Supporting declaration in support of Mills patent application No. 07/825, 845, "Energy/Matter Conversion Methods and Structures".

DRAFT

31. N. J. Gernert, R. M. Shauback, "Nascent Hydrogen: An Energy Source", Final Report 11-1124 to Wright Laboratory, Air Force Material Command (1993).

32. J. M. Niedra, I. T. Myers, "Replication of the Apparent Excess Heat Effect in a Light Water--Potassium Carbonate--Nickel Electrolytic Cell", NASA Technical Memorandum 107167 (1996).

33. HPC writeup with INEL raw data, "Experimental Verification by Idaho National Engineering Laboratory", (1993).

34. Westinghouse STC Report, "Evaluation of Heat Production from Light Water Electrolysis Cells of HydroCatalysis Power Corporation" (1994).

35. Haldeman, C., et.al., "Excess Energy Cell Final Report", MIT Lincoln Laboratory meeting viewgraphs (1995)

36. J. E. Jones, et.al., "Faradaic Efficiencies Less Than 100% During Electrolysis of Water Can Account for Reports of Excess Heat in "Cold Fusion" Cells", J. Phys. Chem., **99**, 6973 (1995).

37. Beamon, J. A., Wade, S. H., "Energy Equipment Choices: Fuel Costs and Other Determinants", U. S. Energy Information Administration/Monthly Energy Review, April, 1996.

38. D. Morgan, F. Sissine, "Hydrogen: Technology and Policy", Congressional Research Service Report for Congress, April, 1995.

39. U. S. Energy Information Administration, International Energy Outlook 1996.

40. J. Carlin, "Environmental Externalities in Electric Power Markets: Acid Rain, Urban Ozone, and Climate Change", Energy Information Administration Renewable Energy Annual (1995).

41. Personal Communication, Dr. Thomas O. Passell, Manager, Deuterated Metals Research, Nuclear Power Group, EPRI, June 4, 1996.

42. Personal Communication, Ernest E. Criddle, University of Ottawa (retired), June, 1996.

43. Personal Communication, George H. East, Mechanical Equipment Group Manager, Senior Principal Engineer, Stone & Webster Engineering Corp., June, 1996.

44. Personal Communication, Dick Mulik, Westinghouse Science and Technology Center, July, 1996.

DRAFT

45. Personal Communication, Stewart Kurtz, Pennsylvania State University, Electrical Engineering Department and Materials Research Institute, July, 1996.

46. Haus, H. A., "On the Radiation from Point Charges", American Journal of Physics, **54**, 1126-1129 (1986).

47. Personal Communication, Barry Turner, National Radio Astronomy Observatory, NRAO Headquarters, July, 1996.

48. Mills, Randell; Kurtz, Stewart; Turner, Barry; "A search for Hydrino - A New Form of Hydrogen", 1996.

49. Personal Communication, Reinhart Engelmann, Professor, Electrical Engineering and Applied Physics Department, Oregon Graduate Institute (currently on leave in Munich, Germany), July, 1996.

50. Engelmann, Reinhart, "Book Review, Unification of Spacetime, the Forces, Matter, and Energy", (1994)

51. Personal Communication, Michael G. Jacox, Lockheed Martin Idaho Technologies Company (currently on loan to Air Force), June, 1996.

52. Personal Communication, Bob Shaubach, formerly Thermacore, Inc., July, 1996.

53. Personal Communication, Nelson Gernert, Project Engineer, Thermacore, Inc., July, 1996.

54. Phillips, Johathan, Declaration in support of HPC patent for "Energy/Matter Conversion Methods and Structures", December 14, 1995.